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Empire Building, Pittsburgh, Penna.

IRON AND STEEL ENGINEER

DECEMBER • 1938

VOL. XV NO. XII

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PLASTIC BINDING U. S. PATENT NO. 1171035 LICENSE NO. 11

BRIGHT

and DRY

From Continuous Special Atmosphere Furnaces Built by The Electric Furnace Company

★ Ferrous and non-ferrous wire — from the finest gauges to the heaviest sizes — is bright annealed uniformly and economically in various types of controlled atmosphere furnaces we have built.

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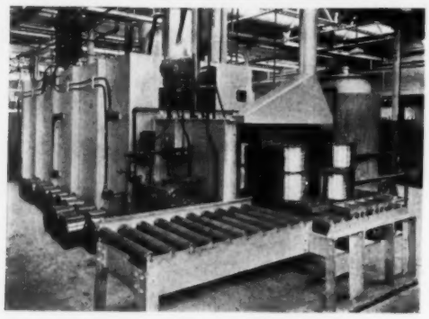

A special atmosphere continuous pusher type furnace for bright annealing both heavy and fine wire on large reels, on spools and in coils.

Other recent installations include furnaces for bright and clean annealing brass, nickel silver and copper wire; improved pit type furnaces for normalizing rod and bright annealing steel wire in coils, as well as furnaces for scale-free hardening bolts, springs, etc., furnaces for billet heating, bright annealing tubing, strip, stampings; carburizing, copper brazing and other heating and heat treating processes.

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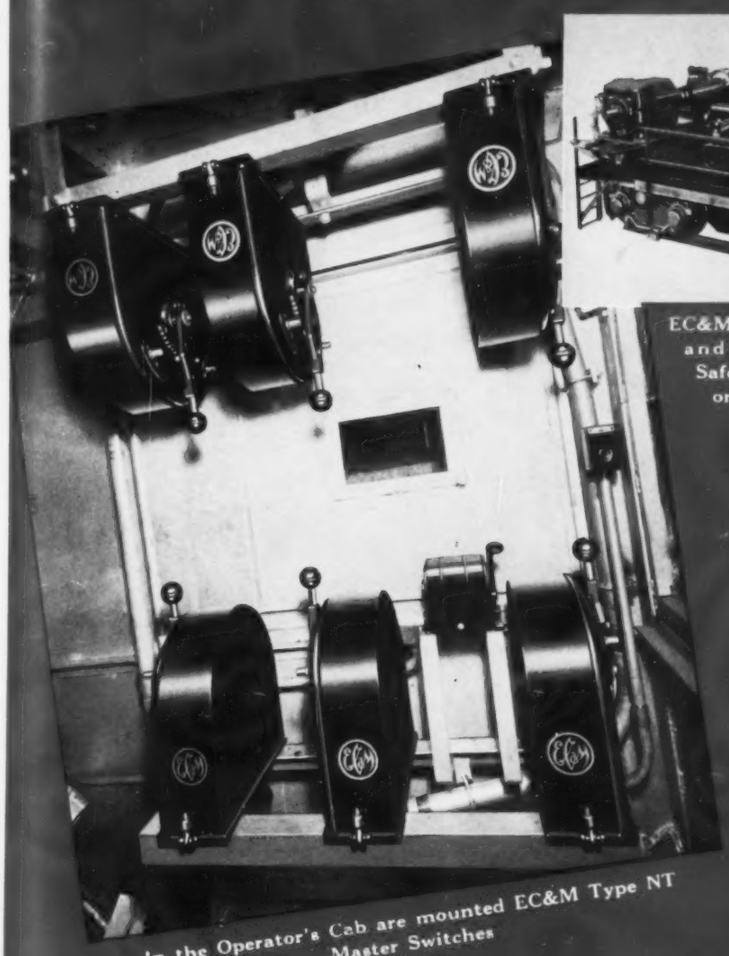
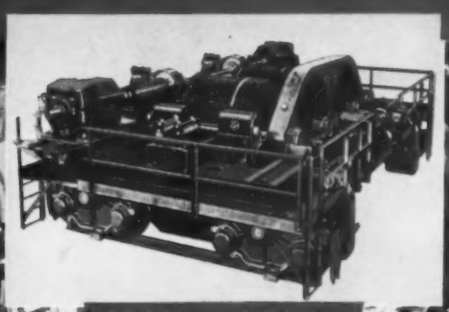
SALEM, OHIO

CONTROL for 250-Ton Ladle Crane

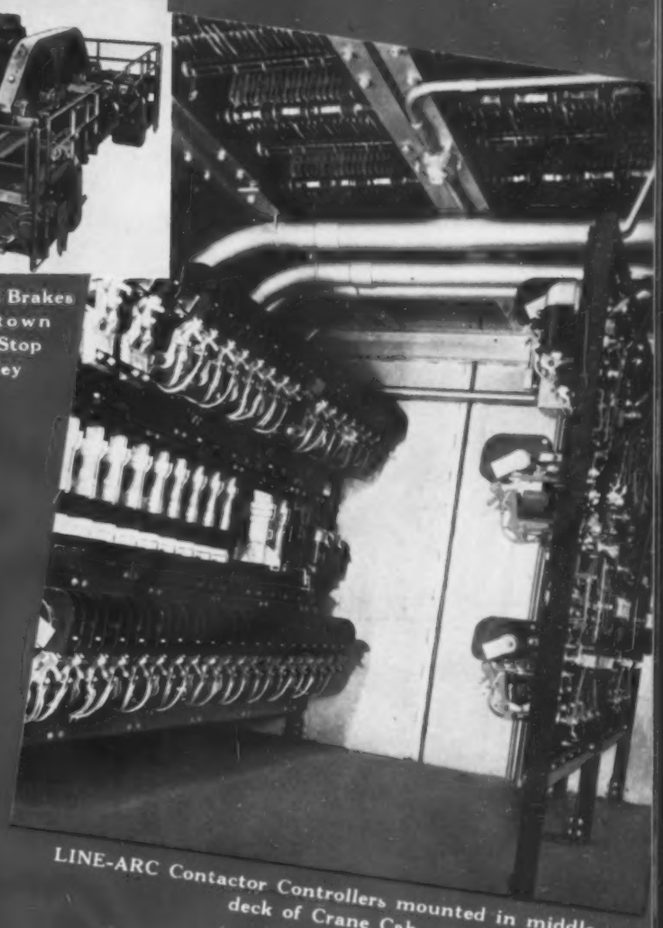
One of 4 Cranes recently equipped throughout with EC&M Control



In the Operator's Cab are mounted EC&M Type NT Master Switches



EC&M Type WB Brakes and Youngstown Safety Limit Stop on the Trolley



LINE-ARC Contactor Controllers mounted in middle deck of Crane Cab

These are some of the important features which influence Ladle Crane Purchasers to write "EC&M Control" into the Specifications.

The Magnetic Brake releases instantly with the EC&M Wright Dynamic Lowering Circuit Hoist Controller. With this control, the brake is not in the divided circuit but instead receives all the current taken from the line on first point lowering, thus insuring quick brake release and permitting inching movements as needed.

EC&M Time-Current Acceleration permits quick spotting of Ladle over Molds when pouring. In this service, the rapid operation of Time-Current Relays under no-load conditions makes it possible to easily take the swing out of the ladle when jumping from one mold to the next.

EC&M Type NT Master Switches are conveniently grouped. Due to the compact design and narrow width, all the EC&M Master Switches can be mounted within easy reach of the operator.

EC&M Duplex Youngstown Safety Limit Stop eliminates Overhoisting Accidents. Operated directly by the hook block, this limit stop brings both hoisting motors to rest simultaneously and quickly by dynamic braking. It is a final check against human error and enables the operator to do better work since it removes the fear of an overhoisting accident from the operator's mind.

EC&M Type WB Brakes have thick Brake Blocks insuring very long life and infrequent adjustment and because there are no rods over the top of the brake wheel, armatures can be rapidly replaced when required.

EC&M LINE-ARC Contactors are fast-operating, have high arc rupturing ability and control the arc scientifically to eliminate wear on arc shields and contacts. New records of contact and arc shield life, made possible by this outstanding development in contactor-design, are still in the making.

When buying Cranes, Specify **EC&M** *Control*

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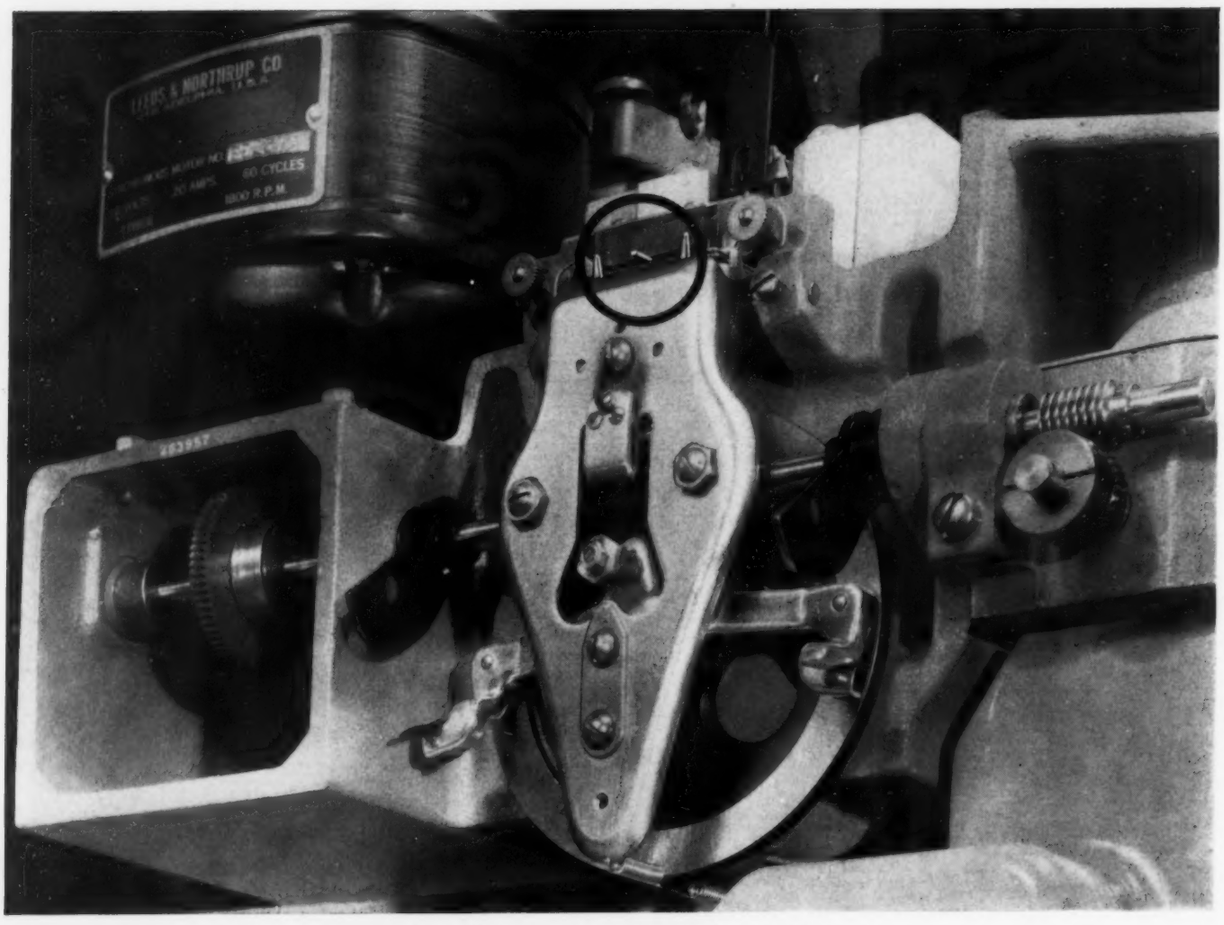
MESTA

HEAT TREATED SPECIAL ALLOY STEEL BACKING UP ROLLS

MESTA MACHINE COMPANY · PITTSBURGH



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Micro-Responsive MICROMAX

PUTS ITS FINGERS ON TEMPERATURE'S PULSE

The Micromax Pyrometer's micro-sensitive, no-clearance Balancing Unit does something of unique benefit to every temperature-recording or controlling problem. . . . Because of it, the Micromax temperature-driven needle *can't move* without the motion being acted on. The appropriate response of fuel valve, recording pen and indicating pointer takes place whenever temperature affects the needle . . . however slightly. Micromax acts early, sets new standards, for recording and for control.

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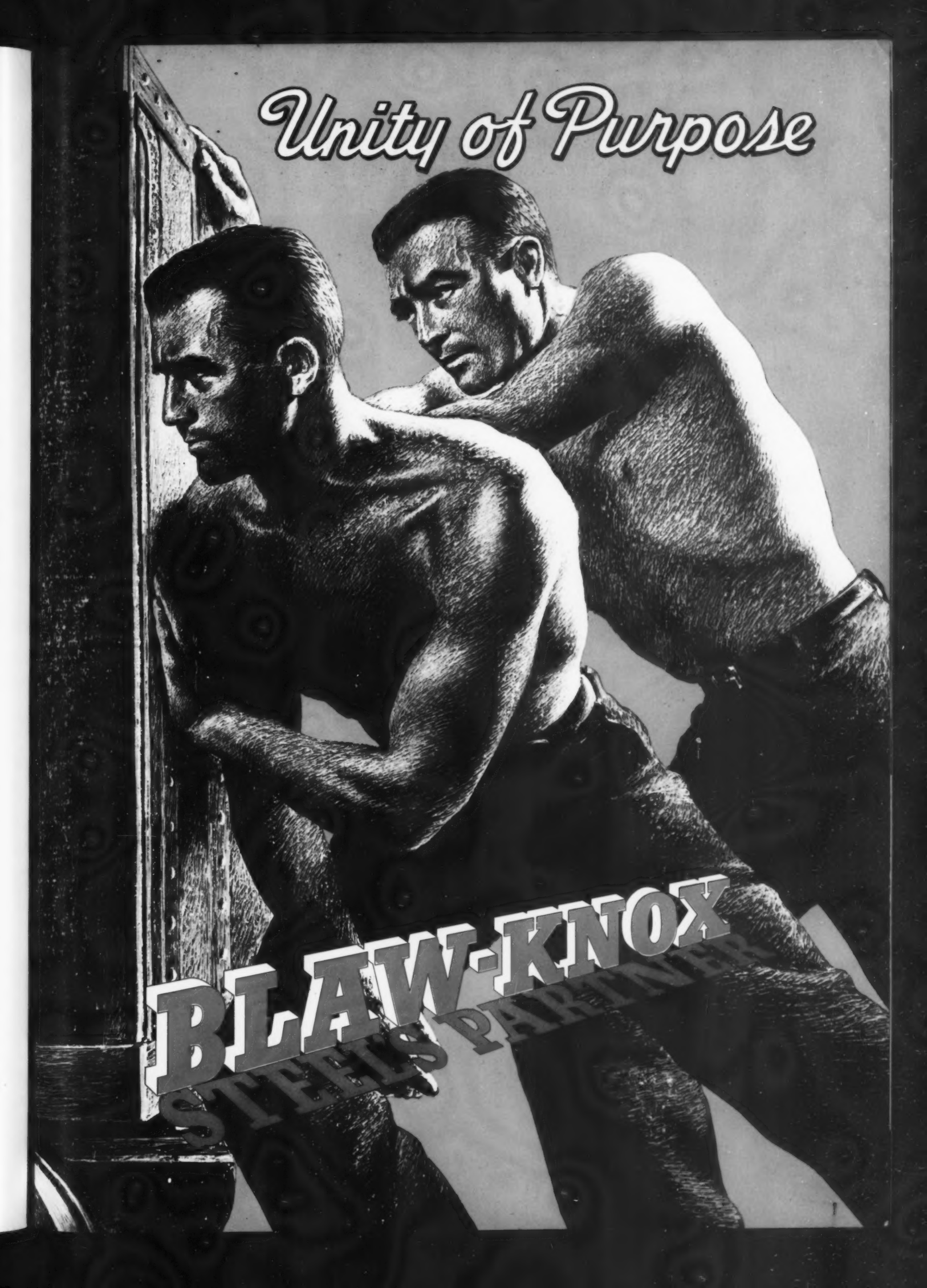
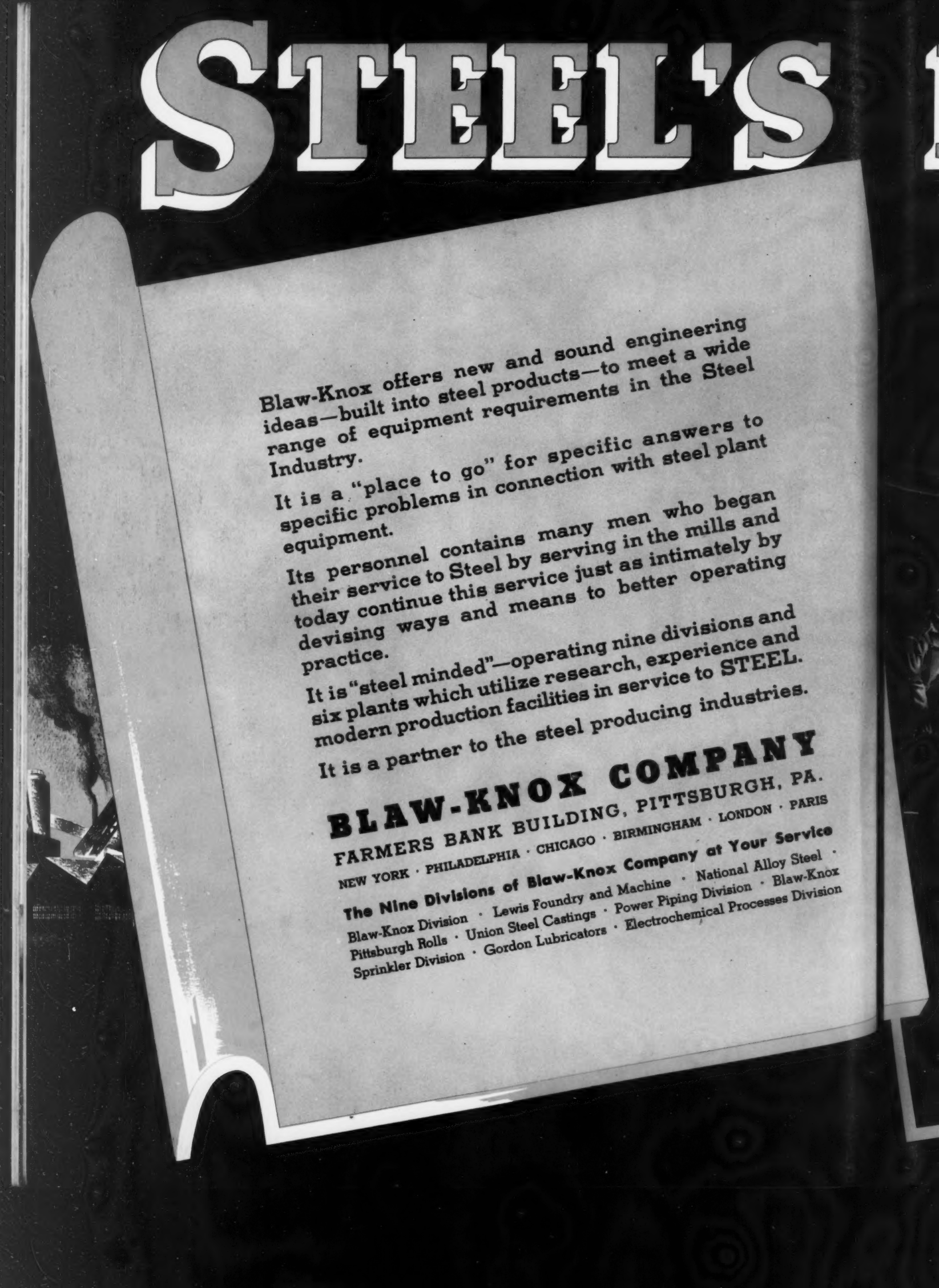

Unity of Purpose
BLAW-KNOX
STEEL PARTNER



Blaw-Knox offers new and sound engineering ideas—built into steel products—to meet a wide range of equipment requirements in the Steel Industry.

It is a "place to go" for specific answers to specific problems in connection with steel plant equipment.

Its personnel contains many men who began their service to Steel by serving in the mills and today continue this service just as intimately by devising ways and means to better operating practice.

It is "steel minded"—operating nine divisions and six plants which utilize research, experience and modern production facilities in service to STEEL.

It is a partner to the steel producing industries.

BLAW-KNOX COMPANY

FARMERS BANK BUILDING, PITTSBURGH, PA.

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Blaw-Knox Ninefold Service to Steel

Partial List of Products

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Blawnox, Pa.

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LEWIS FOUNDRY & MACHINE,
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Pittsburgh, Pa.

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Pittsburgh, Pa.

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Automatic sprinkler systems guaranteed to meet all insurance requirements.

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Pittsburgh, Pa.

Grease lubricating systems for heavy machinery Automatic and mechanical control.

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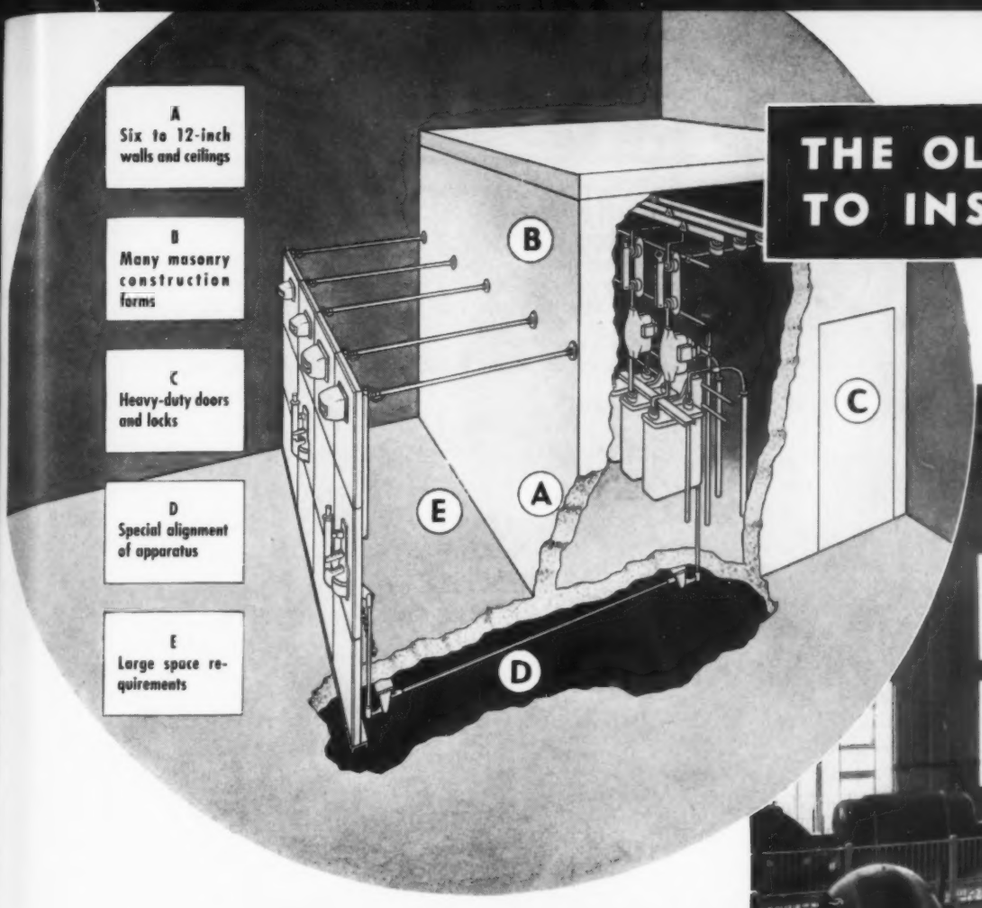
STEELS PARTNER



THE OLD, HARD WAY TO INSTALL SWITCHGEAR

NEW, EASY, SAFE WAY

For Your Pocketbook's Sake, Too . . . Put In Metal-enclosed Switchgear

Any way you look at it, buying metal-enclosed switchgear means economy.

Consider:

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Specify metal-enclosed switchgear for *all* your switching requirements. General Electric, Schenectady, N. Y.

RECOGNITION BY THE N. E. C.

It is significant that, on circuits of 5000 to 15,000 volts, the present National Electrical Code puts metal-enclosed gear in the preferred class. It prescribes that these oil circuit breakers shall have a metal enclosure—or be remotely controlled in a specially constructed fire-resistive vault.

GENERAL ELECTRIC

880-33

Use BILLETEERS
Save · MEN · MONEY · MATERIAL

REPORT OF BILLETEER OPERATION

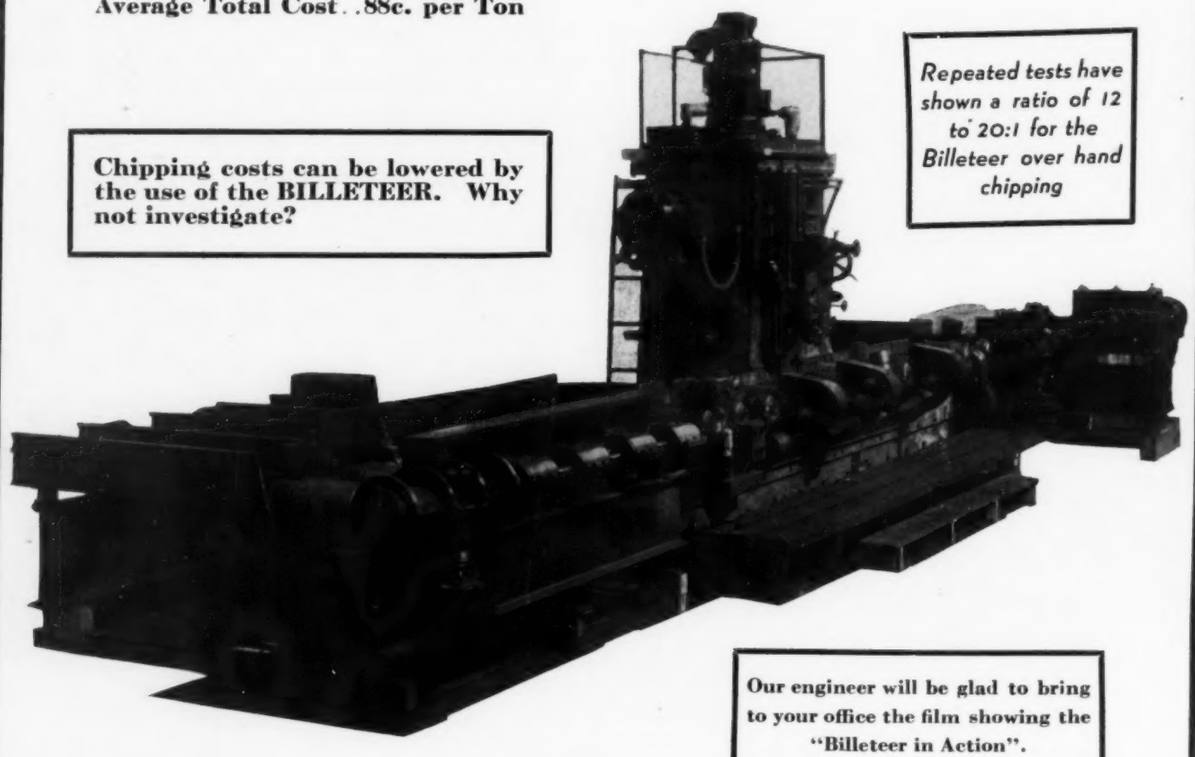
(From Customer's Records)

Period of Operation.....1 Month
Machine Operated.....640 Hours
Total Tonnage Chipped, 2434 Tons
Average per Hour.....3.88 Tons
Class of Steel { Spring Stock / Chrome Vanadium / Hi Sil Manganese
Sizes Handled..... { 4″ x 4″ / 5″ x 5″ / 6″ x 6″
Average Total Cost..88c. per Ton

Compare chipping costs with the performance of the Billeteer which was operated 7 days a week for the period of a month and showed an average output for the entire period of 3.88 tons per hour with an over-all cost of 88 cents per ton. This cost included power, tools, labor, maintenance and depreciation.

Chipping costs can be lowered by the use of the BILLETEER. Why not investigate?

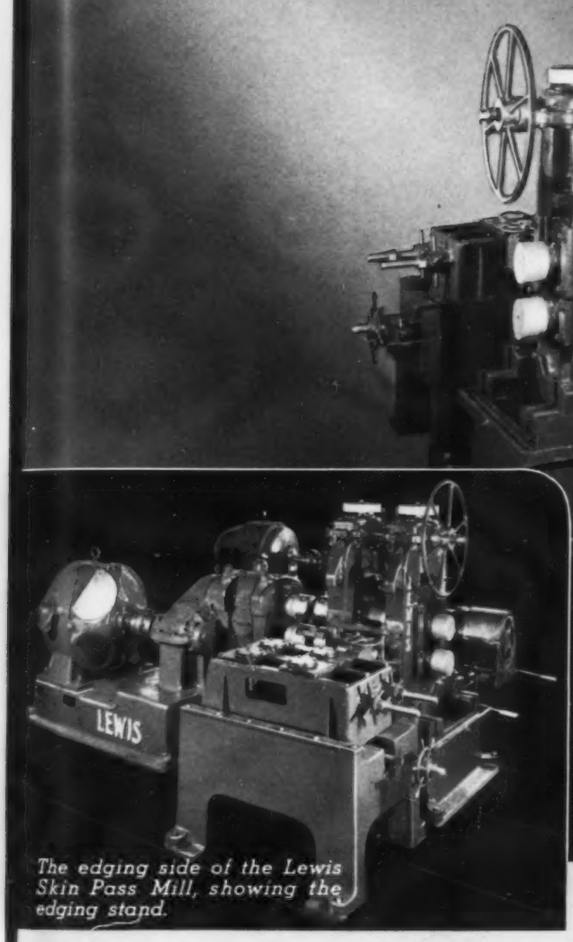
Repeated tests have shown a ratio of 12 to 20:1 for the Billeteer over hand chipping



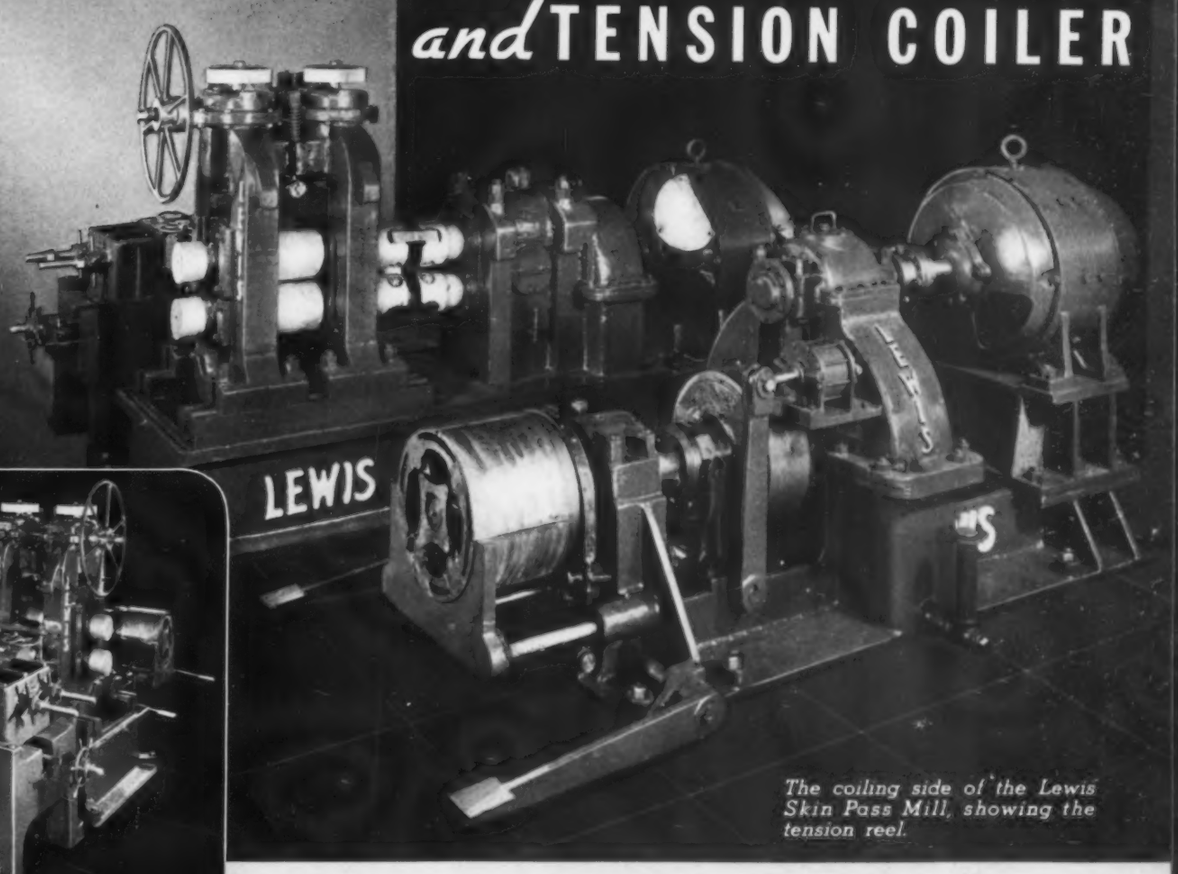
Our engineer will be glad to bring to your office the film showing the "Billeteer in Action".

STEEL EQUIPMENT DIVISION
THE BONNOT COMPANY
CANTON OHIO U.S.A.

LEWIS SKIN PASS MILL with EDGING STAND and TENSION COILER



The edging side of the Lewis Skin Pass Mill, showing the edging stand.



The coiling side of the Lewis Skin Pass Mill, showing the tension reel.

THE LEWIS SKIN PASS MILL cold rolls and edges pre-slit strip and coils it on the delivery side. It enables strip to be rolled at speeds of from 400 to 1200 F.P.M., and delivered accurately edged to meet specifications having close tolerances.

This Lewis Mill is made for brass, copper, aluminum and other non-ferrous metals – as well as steel strip. It is built to conform to the well-known **LEWIS** standard of quality.

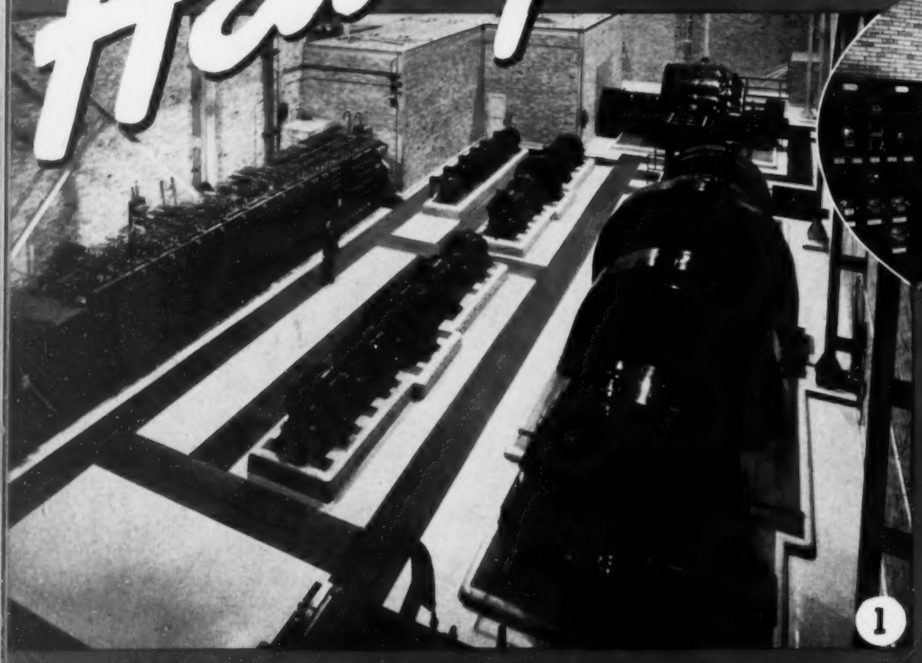
Complete details and prices will be sent you upon request.

LEWIS FOUNDRY & MACHINE

DIVISION OF BLAW-KNOX CO.

PITTSBURGH, PA.

ANOTHER *Heavy Blooming*



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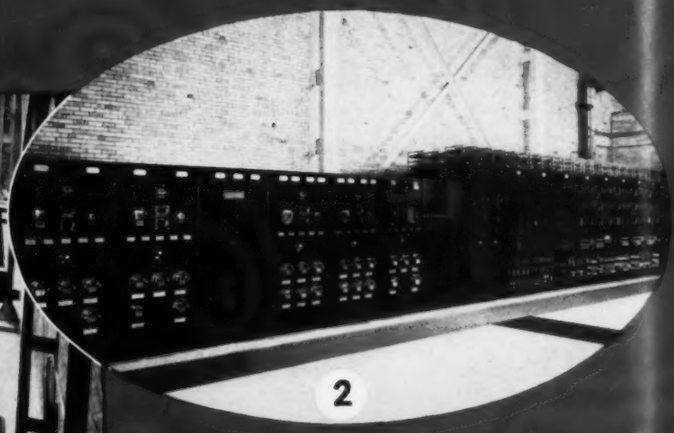
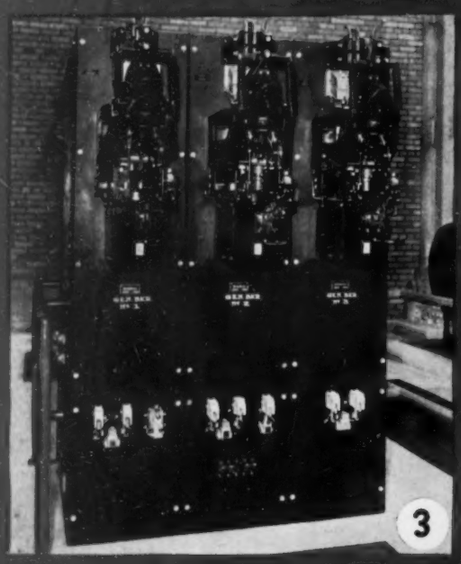


2

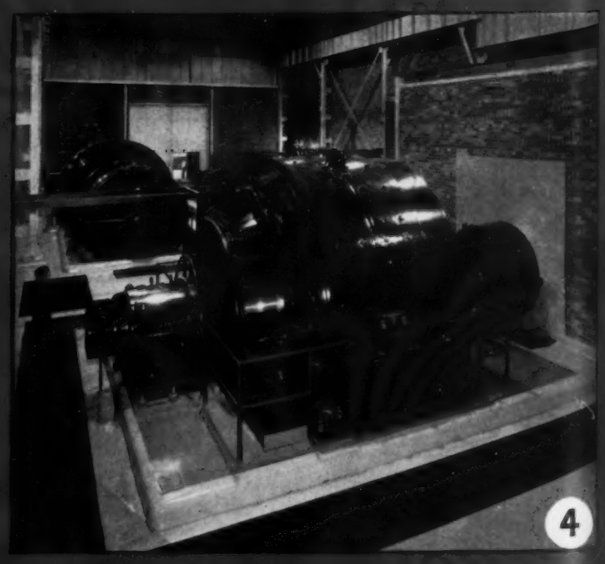
2. Vertical lift, metal-clad switchgear and factory assembled d-c control.

1. View of motor room showing main drive reversing motor and flywheel MG set; also MG sets for d-c variable voltage mill auxiliaries, switching and control.



3

3. Main drive d-c tie panels with heavy-duty circuit interrupters.



4

4. 7000 hp, 40/80 rpm., 700 volt d-c reversing motor.

Westinghouse

Mill

5

6

7

8

9

Complete responsibility for both main and auxiliary drives was again entrusted to Westinghouse in this heavy blooming mill recently placed in operation by the Great Lakes Steel Corporation.

Whenever a mill is projected to produce slabs or heavy blooms—whenever a hard job is to be done—it is only natural for the Steel Industry to think of Westinghouse.

WESTINGHOUSE ELECTRIC & MFG. CO.
Dept. 7-N East Pittsburgh, Pa.

5. General view of mill and table, showing side guard motors.

6. Auxiliary motors at slab shear.

7. Variable voltage slab shear showing shear motors and shear control desk.

8. Motors on manipulator.

9. View showing shear and table motors.

W
WESTINGHOUSE ELECTRIC

Electrical Partner of the Steel Industry

DISTRICT CHAIRMEN

L. V. Black, superintendent of electrical department, Bethlehem Steel Company, Bethlehem, Pennsylvania, was graduated from Pennsylvania State College in 1914. Starting to work immediately, Mr. Black worked his way through successive steps to the post of assistant superintendent of the electrical department of the Bethlehem Plant. In August 1938, he succeeded the late A. J. Standing as electrical superintendent.

▲

Frank P. May, assistant chief engineer, by-product coke works, Carnegie-Illinois Steel Corporation, Clairton, Pennsylvania, was graduated from the School of Electrical Engineering at Purdue University in 1913. Mr. May took his first position following graduation at the Mingo Works of the former Carnegie Steel Company, holding the title of assistant to the chief engineer. In 1916 he was advanced to assistant superintendent of the electrical department, and in 1927 became assistant superintendent of maintenance. In 1933 he was named assistant superintendent of maintenance in charge of the electrical department. He was transferred in 1937 to the Clairton Works of the Carnegie-Illinois Steel Corporation taking the position he holds at the present time.

▲

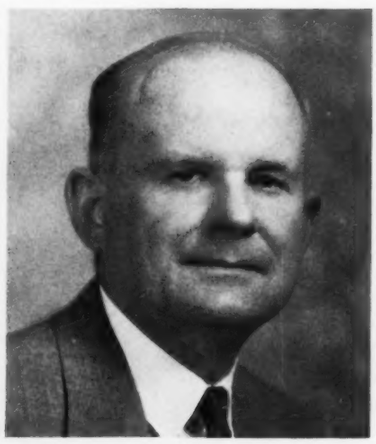
L. R. Milburn, electrical engineer, Great Lakes Steel Corporation, Ecorse, Michigan, was graduated from the University of Michigan with a degree of electrical engineering in June 1918. From July 1918 until December 1918, Mr. Milburn was in the United States Army. In January 1919 he went with the General Electric Company doing testing, complaint, installation, and apparatus sales work. In March 1925, he moved to the Louisville Gas and Electric Company where he did construction work until October 1929, obtaining excellent knowledge of the working of a central station industry. Starting his steel mill career in October 1929 with the Great Lakes Steel Corporation as electrical draftsman, Mr. Milburn remained in this position until 1933 when he was appointed acting electrical engineer. In 1935 he was promoted to electrical engineer.

Pittsburgh District Section

FRANK P. MAY

Detroit District Section

L. R. MILBURN



Philadelphia District Section

L. V. BLACK

A. I. & S. E. 1939

George E. Adams, electrical superintendent, Youngstown Sheet and Tube Company, East Chicago, Indiana, was graduated from the University of Purdue's School of Electrical Engineering in 1914. Mr. Adams worked in the electrical department of the former Illinois Steel Company, Gary Works from 1914 to 1928. During this period he worked at various maintenance jobs, electrical testing engineer, and was assistant electrical engineer at the time he left to go to Youngstown Sheet and Tube Company. Starting as assistant district engineer, Mr. Adams was changed to electrical superintendent in 1935, the position he holds at this time.

▲

Fred M. Sturgess, master mechanic and chief electrician, Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama, was educated at Armour Institute of Technology. Mr. Sturgess completed the Westinghouse Engineering Apprenticeship Course in 1910. His vacation periods were spent working at the former Illinois Steel Company and the former Lackawanna Steel Company. His experience included work in rod mills, chemical laboratory and electrical maintenance department. Mr. Sturgess started as electrical foreman with the American Steel and Wire Company at their Fairfield Wire Works in January 1911, from which position he advanced to the one he now holds with the Tennessee Coal, Iron and Railroad Company.

▲

Frank W. Lorig started to work as tracer and draftsman in 1904 at the Bucyrus Company, South Milwaukee, Wisconsin. After graduating in 1913 from the University of Wisconsin, receiving a B. S. degree in mechanical engineering, Mr. Lorig went to work with the West Penn Traction Company, Pittsburgh, Pennsylvania, as a draftsman.

He started his steel mill career with the American Steel and Wire Company, Cleveland, Ohio, in 1915, as a draftsman. By 1918 he had worked his way to the post of chief draftsman in the construction engineer's office, going from there in 1936 to the post of assistant construction engineer. In 1937 he became construction engineer, holding that position at the present time.

Cleveland District Section

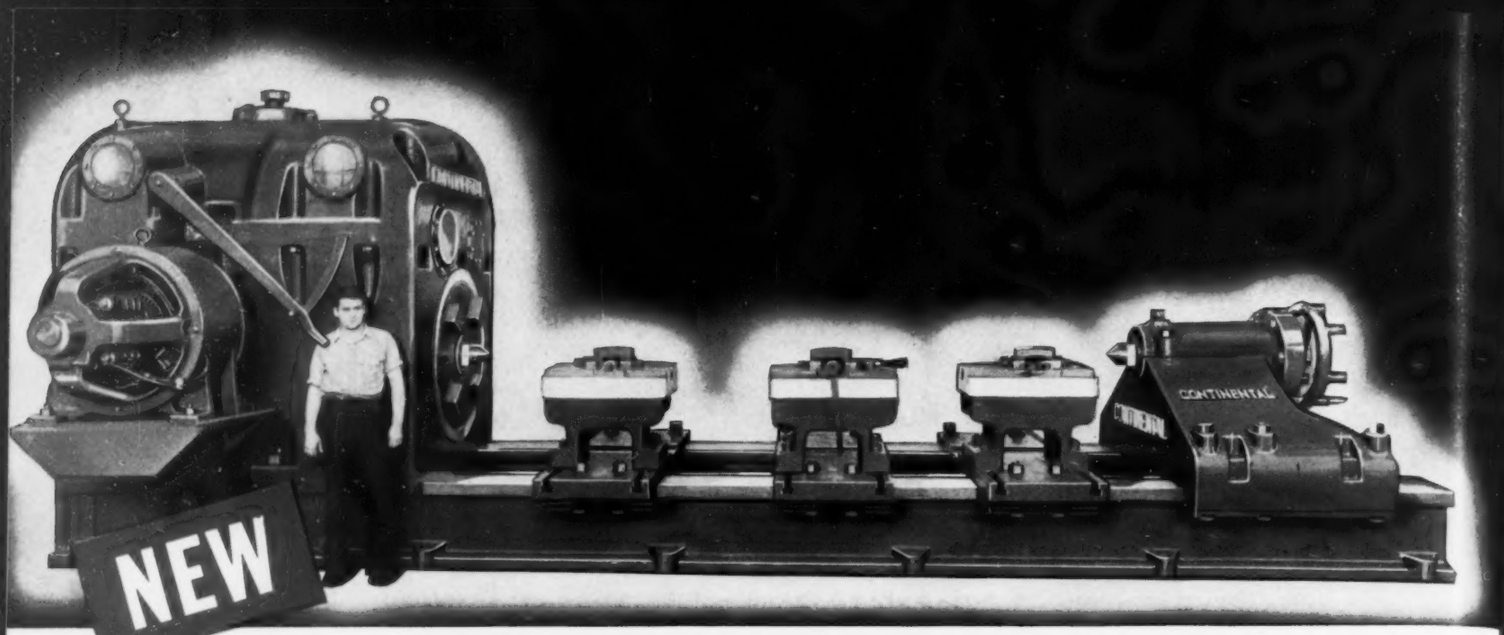
F. W. LORIG

Chicago District Section

G. E. ADAMS

Birmingham District Section

FRED M. STURGESS



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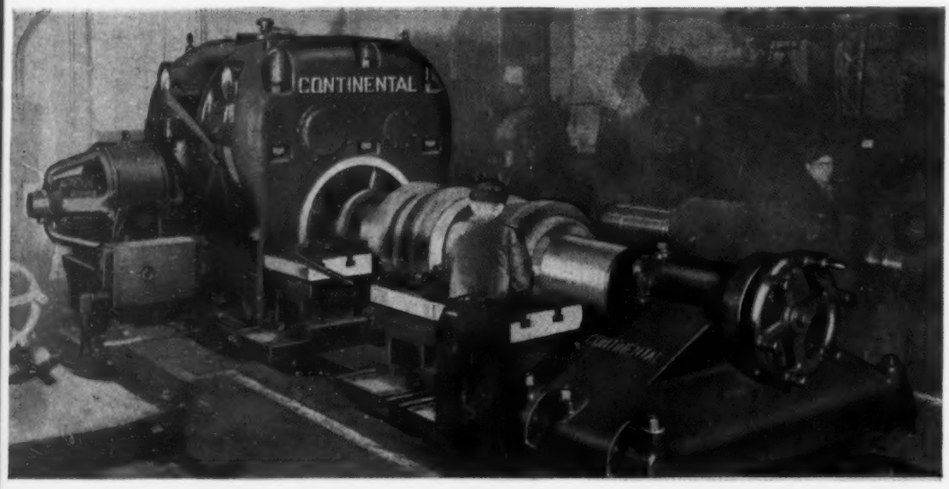

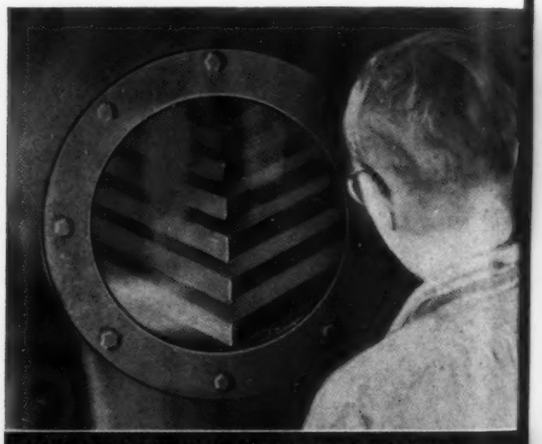

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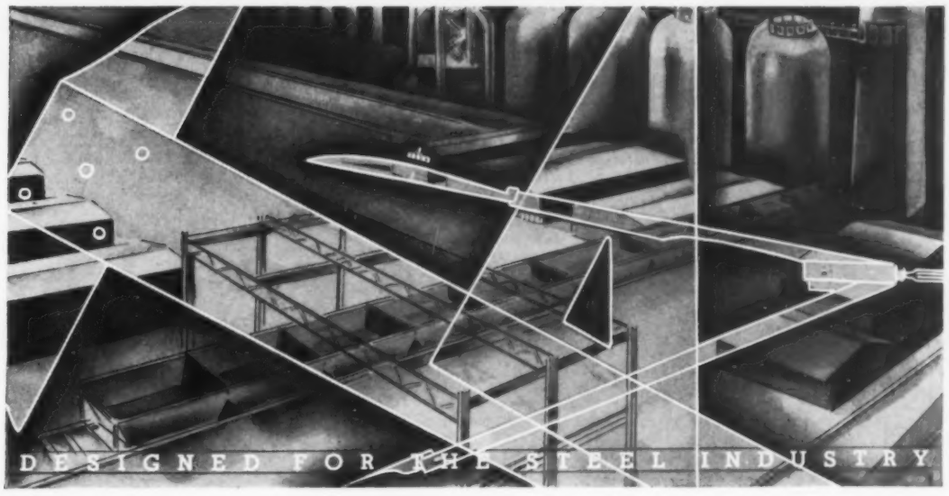

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HEAVY *Oil* BURNING *and* ITS CONTROL

By A. J. FISHER, Fuel Engineer

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MD.

Presented before the A. I. & S. E. Annual Convention, Cleveland, O., September 27, 28, 29, 30, 1938

▲ "OIL has been used for fuel and for heating since the time of Moses; but the mechanical development of the oil burner dates from the middle of the 19th century, and only since 1922, in the United States particularly, has it come into widespread use. Oil in its native state will burn, but not with maximum effect until it is atomized and mixed with air. The history of modern oil heating is the record of the search for simple and efficient methods of preparing heavy oils for complete combustion. In 1861 a mechanic named Werner, employed in one of the refineries of the Russian oil fields of the Caucasus, first suggested that what was then "refuse oil" be used as fuel; his burner, consisting of a series of griddles over which the oil trickled and burned was widely used though not patented until 1867. In 1862 two experimenters took out patents on an oil burner which solved the combustion problem by introducing the oil into the furnace in a gaseous state, the heavy oil first being heated and made to give off lighter oils. In 1863 Brydges Adams introduced into America the first spray burner, and in 1866 Ayden brought out a burner using hot air to atomize the oil and Spakorsky on using superheated steam. Spakorsky's method was later embodied in an oil burner by Thomas Urquhart, an American at that time in the employ of a Russian railway".

A. J. FISHER, the author, is Fuel Engineer of the Maryland Plant, Bethlehem Steel Company.

Oil was discovered in America in 1859, at Titusville, Pa. During the first year only 2,000 barrels were produced. Since then, each successive year, the production and demand have increased until in 1937, the production amounted to 1,277,653,000 barrels in the United States alone.

The increase in the oil production of California and Texas about 1900 attracted general public interest to oil burning. In 1902 and 1903 the U. S. Naval Liquid Fuel Board investigated burners of all kinds, and turned in a favorable report in 1904. The report was accepted at once and all the new vessels were designed for oil and many of the older ships were changed to the new fuel.

The early iron and steel plants were originally located near the coal fields because coal was the greatest tonnage of all raw material used. Modern methods of fuel engineering have reduced the amount of coal required by the average steel plant by the utilization of by-product tars and gases, and by the use of fuel oil, so that now the economical steel plant may be located near the ore field and the steel consuming center that it is to serve.

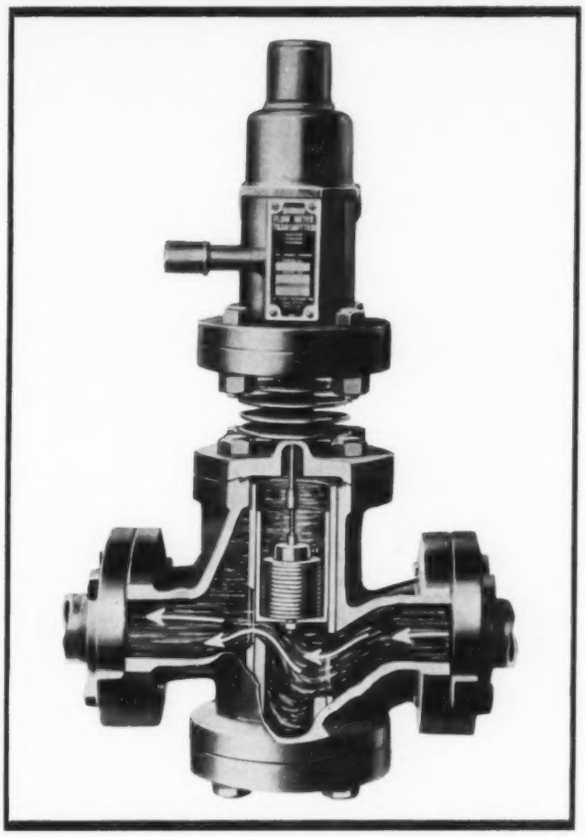


FIGURE 1—Area type fuel oil meter.

Oil was not used by the steel industry during its formative period. It was not until the internal combustion engine reached a practical state of development that crude oil was produced in considerable quantities. However, this type of engine used only the lighter and more volatile distillates from the crude oil. The residue oil became available for industrial and domestic uses in large quantities and at low prices.

The iron and steel industries were the big fuel consumers but they were set up for coal and knew nothing about burning oil. However, the absorption of this cheap fuel was an economic necessity. It was first applied to boilers and then to open hearth furnaces, both large consumers of fuel, whose degree of regulation and changes in furnace atmospheres were relatively unimportant at that time.

The first development period in the burning of fuel oil was from 1861 to 1932. This was the "Hand Controlled Period of Fuel Oil Burning". During this time all kinds of burners were developed, for heating forges, heating furnaces, drying ovens, melting furnaces, and boilers, etc., and, at the same time, considerable effort was given to the development of hand controlled valves. During this period the job of burning the fuel was of primary importance and consequently little or no thought was given to controlling for temperature, or temperature and atmosphere.

The purpose of this paper is to discuss the second development period in the burning of fuel oil which is from 1932 to date and may be called the "Automatic Controlled Period of Fuel Oil Burning". It consists of the dovetailing of temperature or pressure recorder con-

FIGURE 2—Potentiometer with air operated control system.

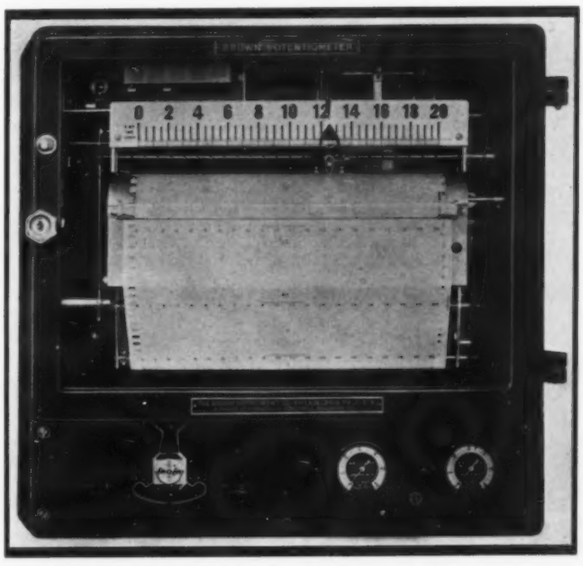
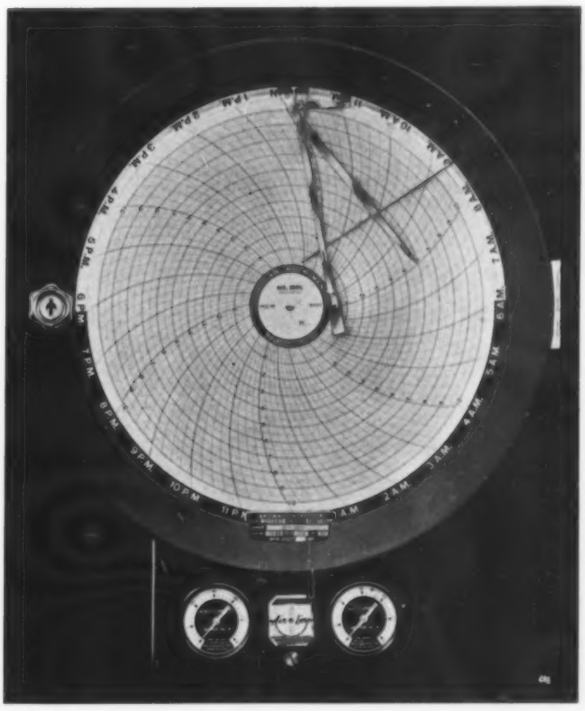


FIGURE 2a—Another type of potentiometer with air operated control.



trollers, fuel oil control, oil burners, and furnaces into a unified complete oil system to obtain a specific required result.

This latter period has seen fuel oil applied on small furnaces with very close regulation, jobs heretofore, using only clean gaseous fuels.

The most important element in the design of an oil burning system is the furnace. Its shape, hearth area, volume, and combustion chambers are most important. The furnace must be a compromise between the requirements of the material to be heated and the oil burning equipment. The usual procedure is to design the hearth of the furnace to suit the material that is to be heated, then to design or select the proper oil burning equipment that will produce the character of flame desired, and then to design the furnace to suit the oil burning equipment.

The subject of proper furnace design is a difficult one. Information and knowledge is increasing rapidly. The furnace engineer who has had an opportunity to review a number of existing installations and who has a knowledge of the laws of heat transmission, radiation, chemistry of combustion, velocities of flue gases, etc., will be most likely to arrive at a good design.

Of course oil burning has its limitations. Generally speaking it can be used to best advantage on large furnaces using considerable quantities of fuel. The small furnaces that require definite atmospheres and flame characteristics are generally not suited to fuel oil burning.

The primary duty of the fuel engineer is to provide the type of furnace and equipment that will give satisfactory results, and his secondary and most important duty is to explain thoroughly to the operating personnel how it works and the function of each piece of equipment. Checks should be made from time to time to assure that all instruments, regulators, gauges, etc., are calibrated and functioning properly and adjustments made when necessary to assure the most efficient operation. This operating problem in itself is of major importance, and is the one that is most generally neglected. Careless operators can render any oil burning system worthless in a very short time.

The usual and best procedure is to have well trained instrument men visit the furnace every day and confer with the heater on the operation of the equipment. Thus any troubles are adjusted before they become chronic.

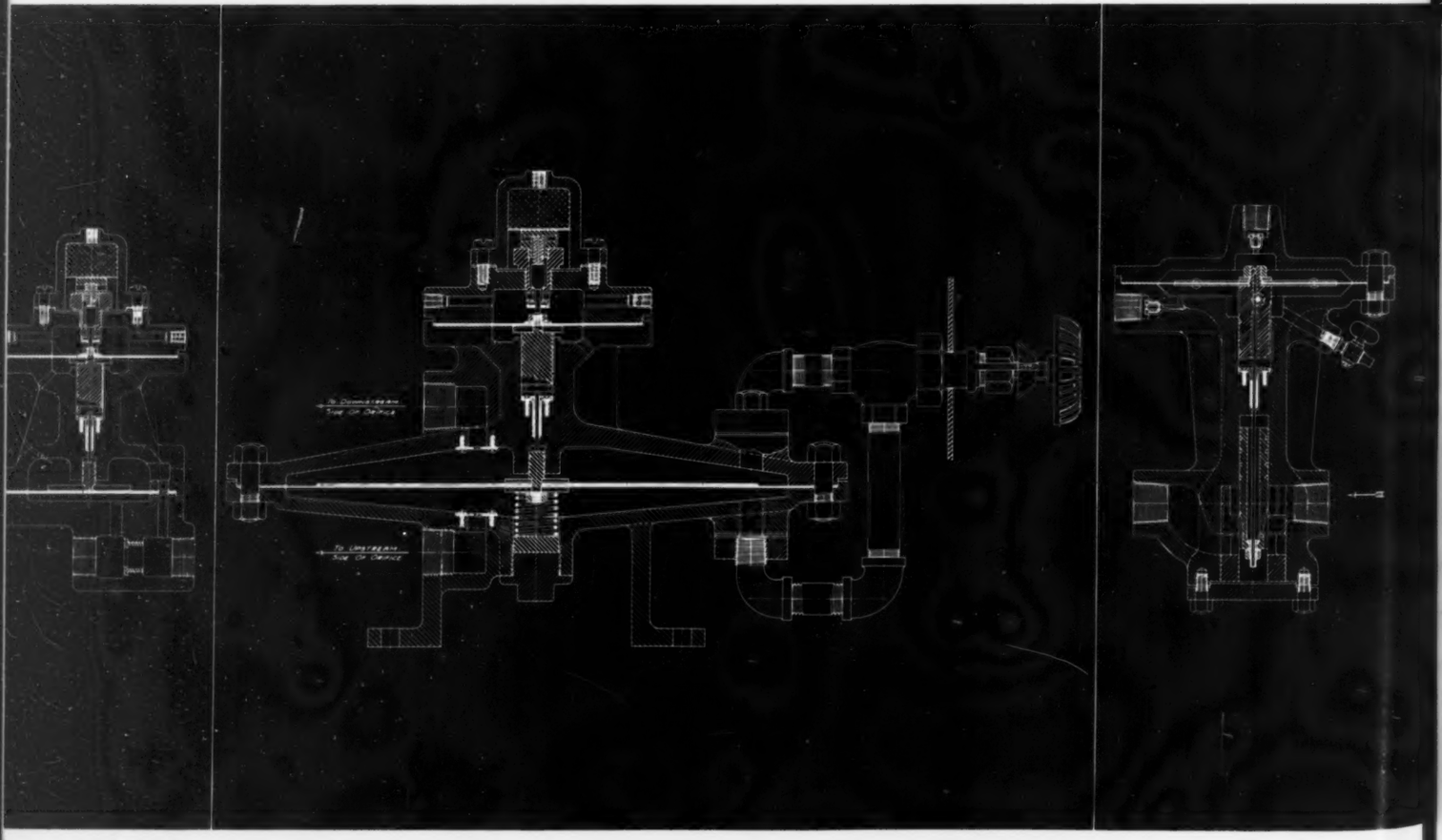
Following is a brief description of oil burning equipment and controls that the writer has become familiar with and has used with good results. There are undoubtedly ways and means of burning fuel oil at variance with the methods set down in this paper; oil burners and control systems that would give equally good results. However, the author has chosen to confine this paper to his own experience.

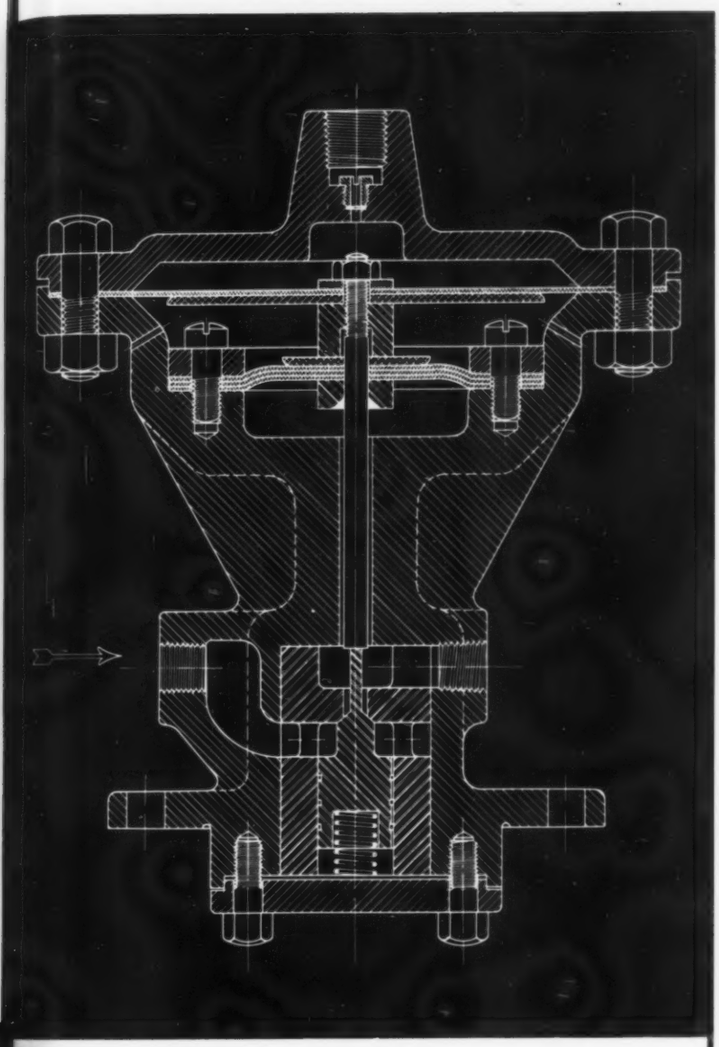
Fuel oil burning systems are composed of units which perform specific jobs in relation to the whole system. In order to more clearly understand the system layouts, an understanding of the prime individual pieces of equipment is necessary.

FIGURE 3—(Left)—Oil differential static converter.

FIGURE 5—(Right)—Automatic oil flow regulator.

FIGURE 4—(Center)—Air differential static converter.





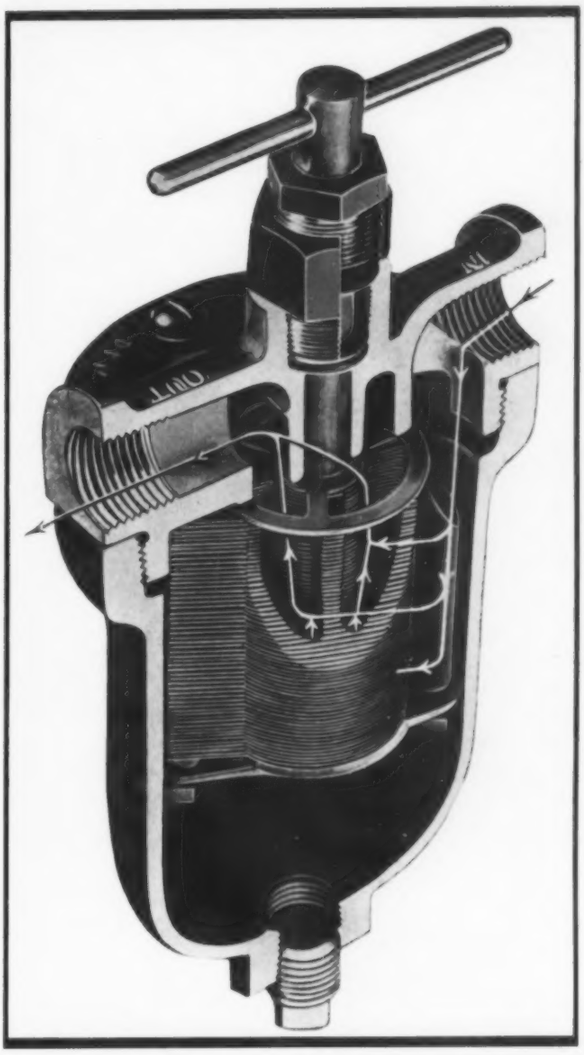


FIGURE 6—(Upper left)—Automatic oil pressure regulator

FIGURE 7—(Lower left)—Combustion regulator for air-oil ratio.

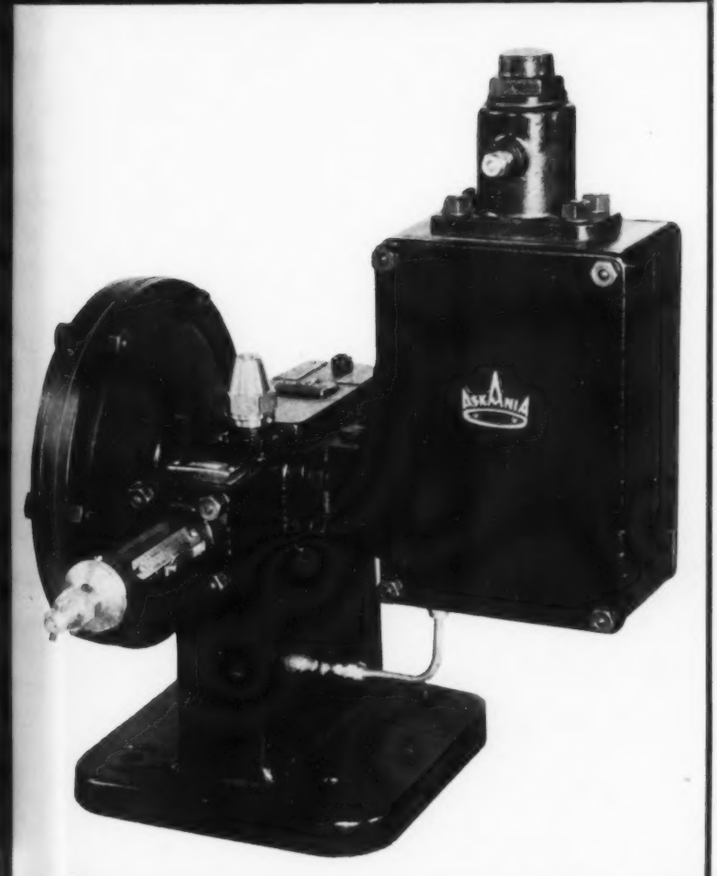
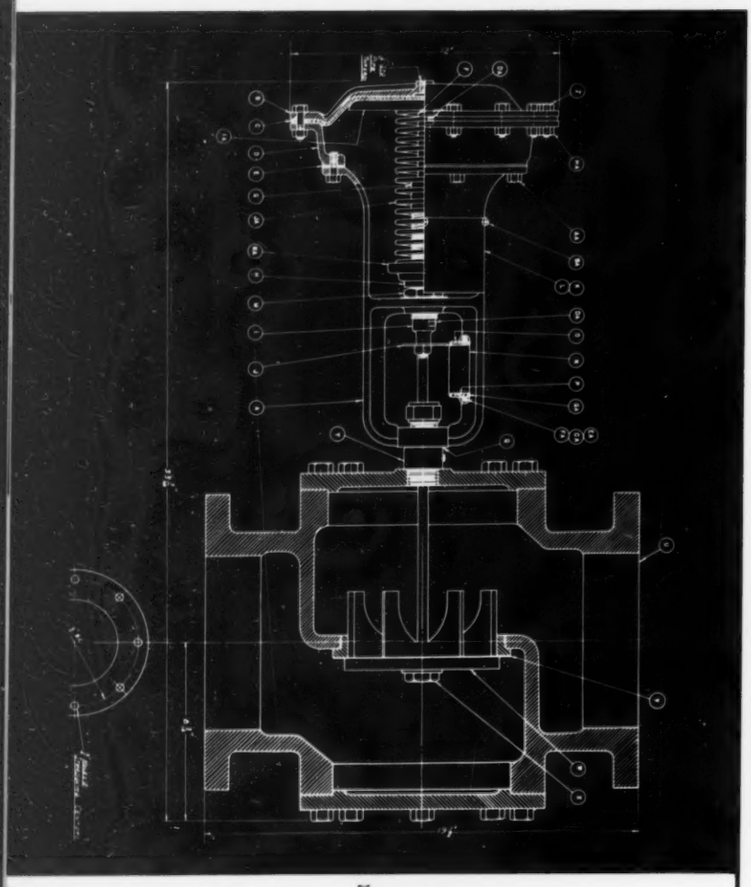
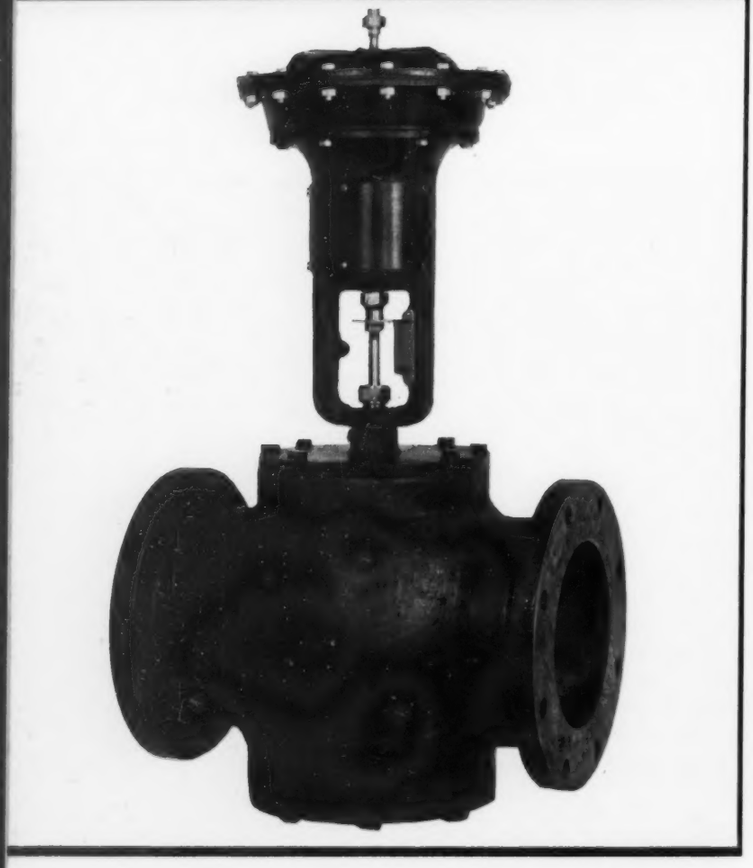


FIGURE 8—(Above)—Fuel oil strainer.

REGULATING AND CONTROLLING DEVICES

The area type flow meter fits into the oil line with the same flange spacing as a 250 lb. 2″ valve. This type of meter is particularly adapted to the measurement of the flow of heavy oils and tars. The oil flow is through the orifice built into the meter body. The differential pressure across the orifice acts on the top and on the bottom of the piston. This differential pressure, which is mathematically equal to the weight per unit area of cross section, causes the piston to move and uncover more or less of the orifice in proportion to the rate of flow. The position of the piston with respect to the orifice is therefore a measure of the rate of flow. By means of an inductance bridge telemetering system the position of the piston is accurately transmitted





FIGURES 9 and 9a—Diagrammatic and photographic views of air operated controller valve.

electrically to a recording instrument calibrated in terms of flow. In some instances this instrument also totalizes the flow, while in others, control operations as a function of flow are incorporated. (See Fig. 1)

Charts made by this meter are shown by Figures No. 34 and 37.

The instrument illustrated in Fig. 2. is the type used for recording and automatically controlling the temperature of oil fired furnaces. This instrument employs either a thermocouple or a radiation tube as the temperature responsive element.

The control index is set at the temperature to be maintained in the furnace. Should the temperature depart from this value, the control mechanism varies the air pressure, 0 to 15 lbs., on an automatic pressure or flow control valve to regulate the fuel supply to the furnace. This type of air operated temperature controller automatically regulates the fuel supply to satisfy the loading in the furnace. If the load in the furnace is particularly light the fuel valve will throttle near its closed position and if the load in the furnace is heavy the fuel valve will throttle nearer its open position. This permits the furnace operator to set the instrument for the desired temperature and he then carries a load in the furnace consistent with operating conditions, knowing that the instrument will automatically regulate the fuel supply to meet his load conditions.

This unit in Fig. 3 measures the differential pressure created by the flow of oil past an orifice, subtracts the pressures, and multiplies the result by three and transposes it into a single static air pressure.

This is accomplished by means of an orifice which is connected on each side to a diaphragm. The diaphragm transmits its resultant force through a pin and stuffing box to a stabilizing piston, air diaphragm assembly and air valve. The underneath side of the air diaphragm is open to atmosphere. The size of this diaphragm is one-third the size of the oil differential diaphragm. The force from the oil differential diaphragm opens the air valve admitting air pressure on the air diaphragm until the force of the two diaphragms are equal.

The air pressure in the chamber is therefore three times the differential pressure across the orifice, and can be connected by means of piping or tubing to the air flow regulators, etc.

Fig. 4 is the same in principle as the oil differential static converter, shown in Figure 3, except it is separate from the orifice, has a multiplying ratio of 42 to 1, and has a by-pass valve and orifices whereby the differential from the orifice may be decreased, thus changing the scale or range of the unit.

Fig. 5 consists of an enclosed diaphragm with restricted ports and stabilizing cups attached to a

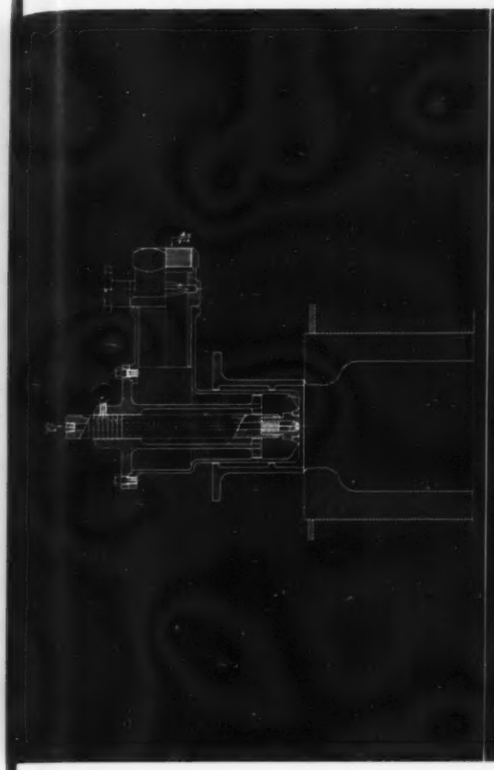


FIGURE 10—Manual air adjusting short flame oil burner.

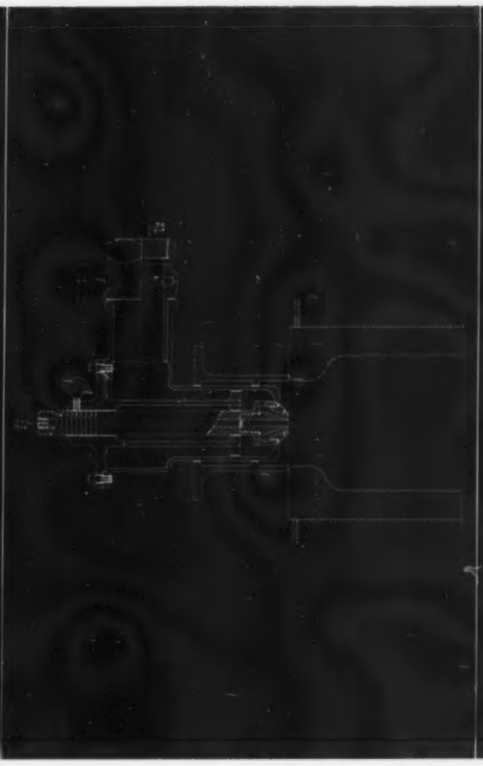


FIGURE 11—Manual air adjusting long flame oil burner.

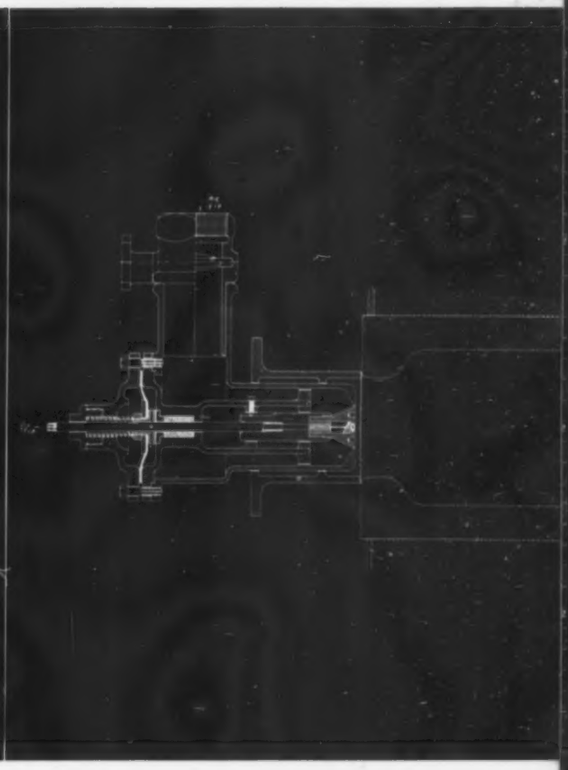


FIGURE 12—Automatic air adjusting short flame oil burner.

FIGURE 13—Automatic air adjusting long flame oil burner.

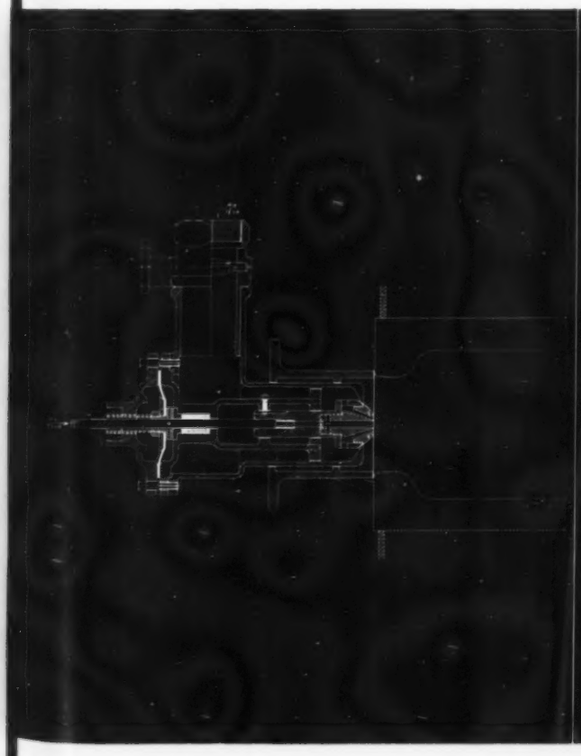
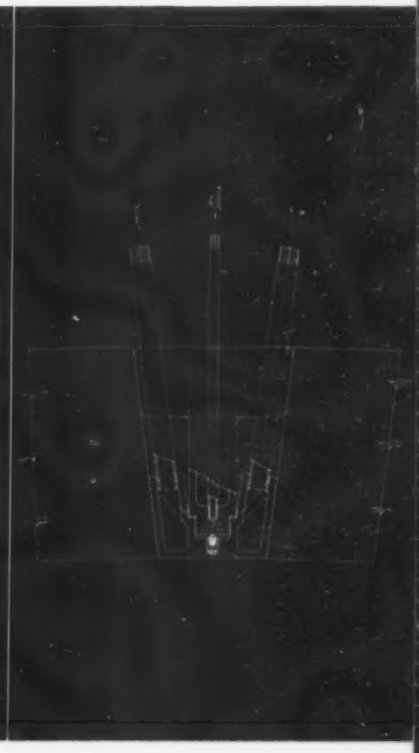
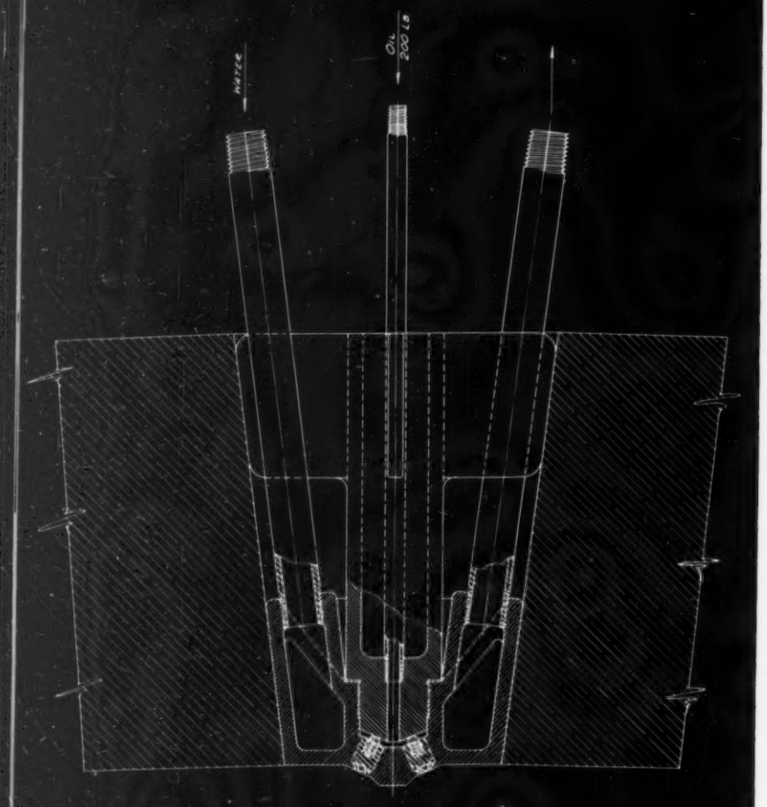
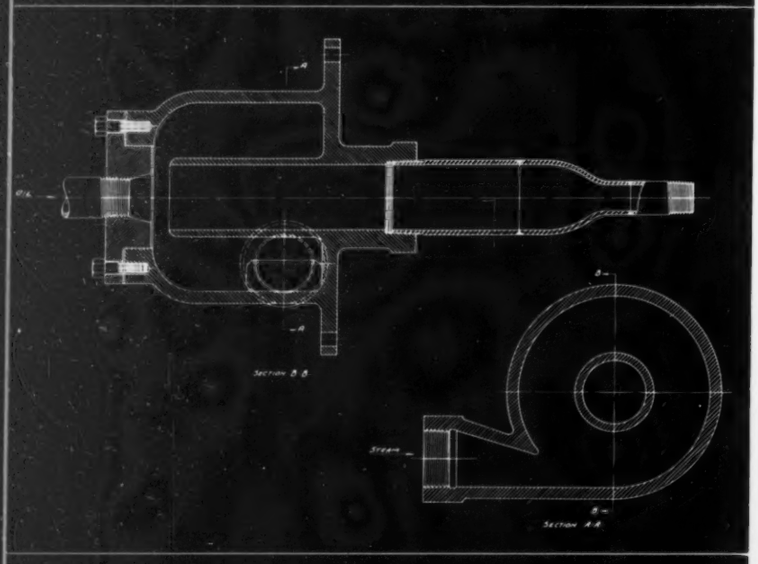


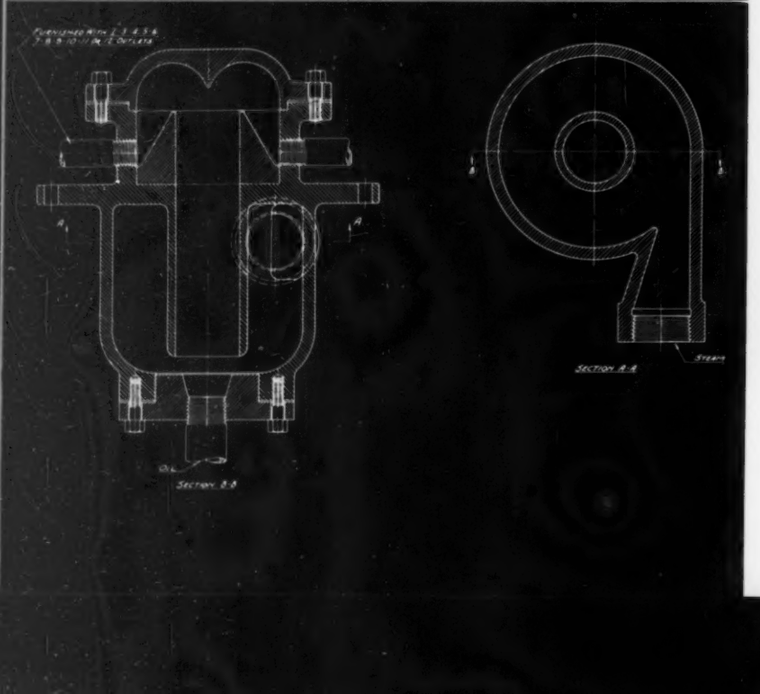
FIGURE 14—Manual air adjusting short flame steam oil burner.

FIGURE 15—Single jet water cooled mechanical oil burner.









piston valve by means of a very small stem working through a special stuffing box.

The ports on the valve are designed to suit the maximum quantity of oil that is desired to regulate or control.

An air pressure, 0 to 15 lbs., proportional to the flow of the oil is connected to the top side of the diaphragm, and an equivalent pressure, 0 to 15 lbs., from the air operated temperature or pressure controller is connected to the bottom side of the diaphragm. The diaphragm moves in either direction until the two pressures are equal. Thus any increase or decrease in air pressure from the controlling instrument will open or close the valve.

This regulator (Fig. 6) is composed of two diaphragms and a valve connected and operated by a common stem.

The top diaphragm receives an air pressure from the controlling instrument, 0 to 15 lbs., and is balanced by the oil pressure 0 to 60 lbs. The chamber between the diaphragms is open to atmosphere. The area of the top diaphragm is designed to suit the controller while the area of the bottom diaphragm parallels the operation of the oil burner.

The ports of the valve are designed to fit the maximum quantity of oil that is desired to regulate or control.

An increase or decrease in the air pressure from the controller will open or close the valve until it is balanced, thus increasing or decreasing the oil pressure as required.

FIGURE 16—(Top)—Multi-jet water cooled mechanical oil burner.

FIGURE 17—(Center)—Single jet steam oil mixer.

FIGURE 18—(Bottom)—Multi-jet steam oil mixer.

In Fig. 7 the regulator employs the use of the jet pipe principle to transform a minute flow impulse into a powerfully developed force. It consists of a diaphragm connected to an orifice in the air line balanced against a sylphon bellows connected to the oil differential static converter. (See Figure 5.) The jet pipe, through relays, stabilizers, etc., operates a hydraulic piston connected to a butterfly valve in the forced draft air line. An adjustable hand wheel operates a double fulcrum bar between the air diaphragm and the oil bellows which changes the relation between the quantities of air and oil delivered to the furnace as desired.

The fluid to be filtered enters the filter, (Fig. 8) fills the outer casing or sump and passes through the space between discs to open passages between the "spokes". All solids too large to pass the space between the discs are retained on the outer edges of these discs. The central space within the stack of discs is connected to the filter outlet, and provides a means of egress for the filtered fluid.

By turning the handle of the filter, the cleaning blades rotate between the discs and remove any dirty particles between them. Because of the shape and location of these blades all solids stopped by the filter discs

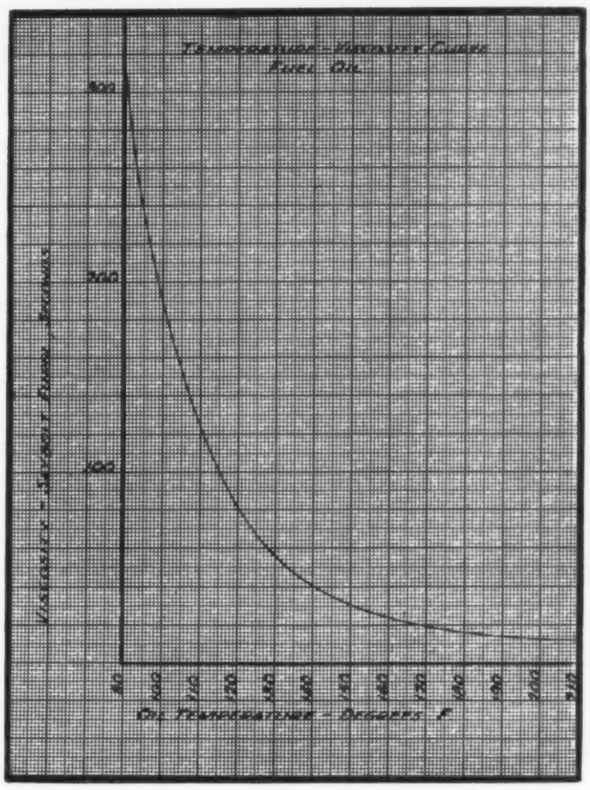


FIGURE 19—Chart showing temperature—viscosity relation for Bunker C fuel oil.

are removed, regardless of whether they merely adhere to the edge of the discs, or are actually lodged between them.

The air operated diaphragm valve is so constructed that at zero pounds of air the valve is closed and at fifteen pounds the valve is open. The moulded rubber diaphragm has characteristics that permit uniform travel of the valve stem and disc in opening or closing for definite air pressures as applied to the diaphragm and opposed by the spring. (Fig. 9.)

OIL BURNERS

There are a considerable number of combinations of oil burners and atomizers. A complete digest of all the forms would take too much space in this paper. The following is, therefore, a description of the basic or primary oil burners. The other forms are derivations of these burners.

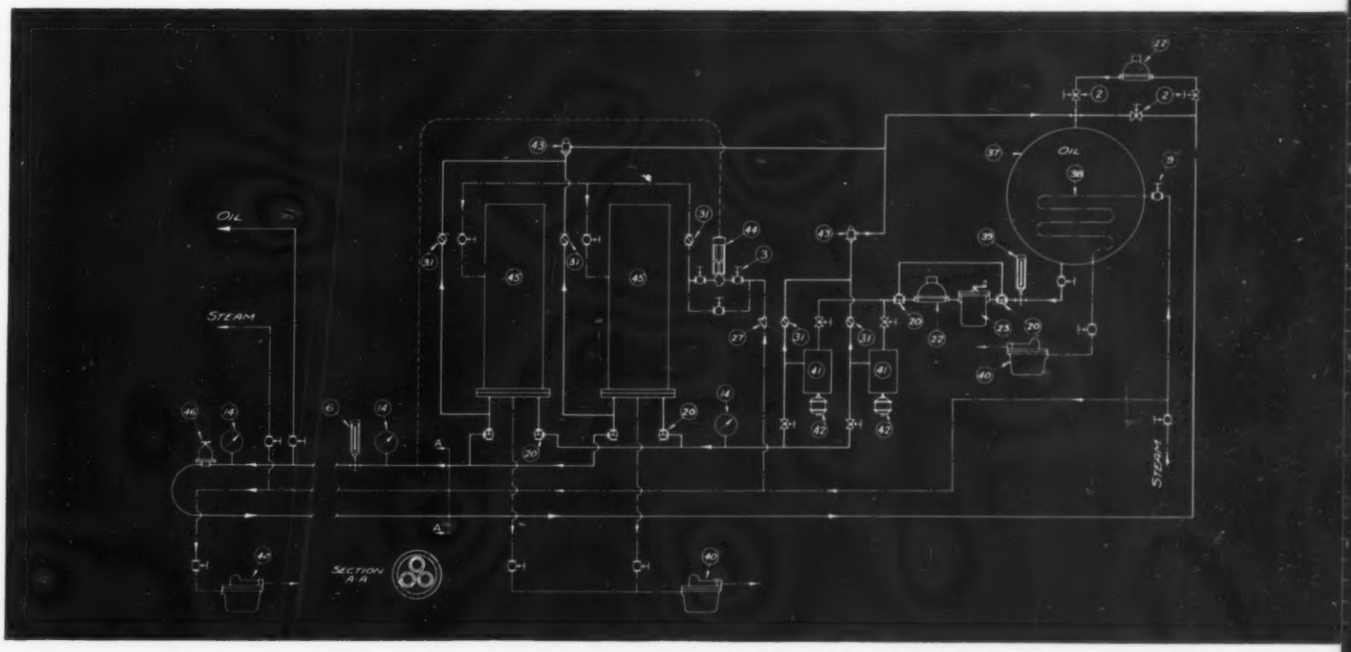
This burner uses air at 1½ lb. and oil at 75 lb., preheated to 180 degrees—225 degrees F. The oil is conducted through the burner proper by means of a protected tube which keeps the air from chilling the hot oil. The oil is atomized mechanically at the burner tip to a cone of about 60 degrees and is spread at once to 180 degrees by means of the back draft created by the anti-stream lined oil tip in the air stream. The confluence of the oil in the air stream creates the desired mixing and character of flame. (See Fig. 10.)

The air is turned completely on or off at the butterfly valve and is regulated by sliding the oil feed pipe in or out to uncover an annular air orifice between the oil atomizer at the burner nose.

A collar on the burner nose is used to adjust the necessary amount of secondary or induced air. This amounts to approximately 50 per cent of the air for combustion.

The burner is centered on the tile by means of a

FIGURE 20—Schematic layout of central unloading station in fuel oil system.



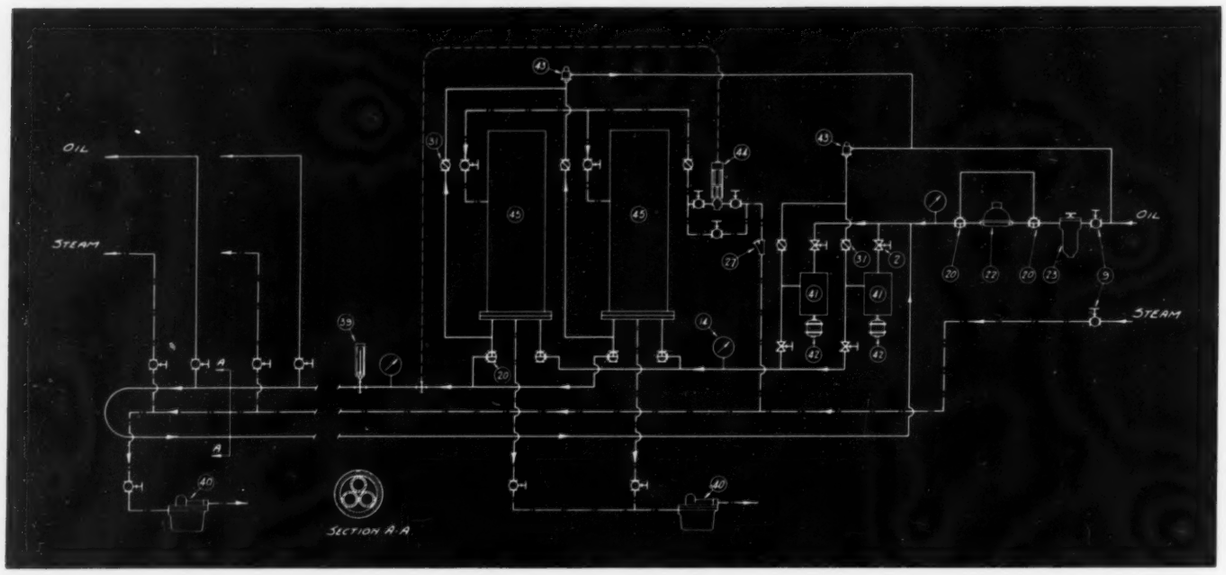


FIGURE 21—Diagram of booster and heater installation used in fuel oil system.

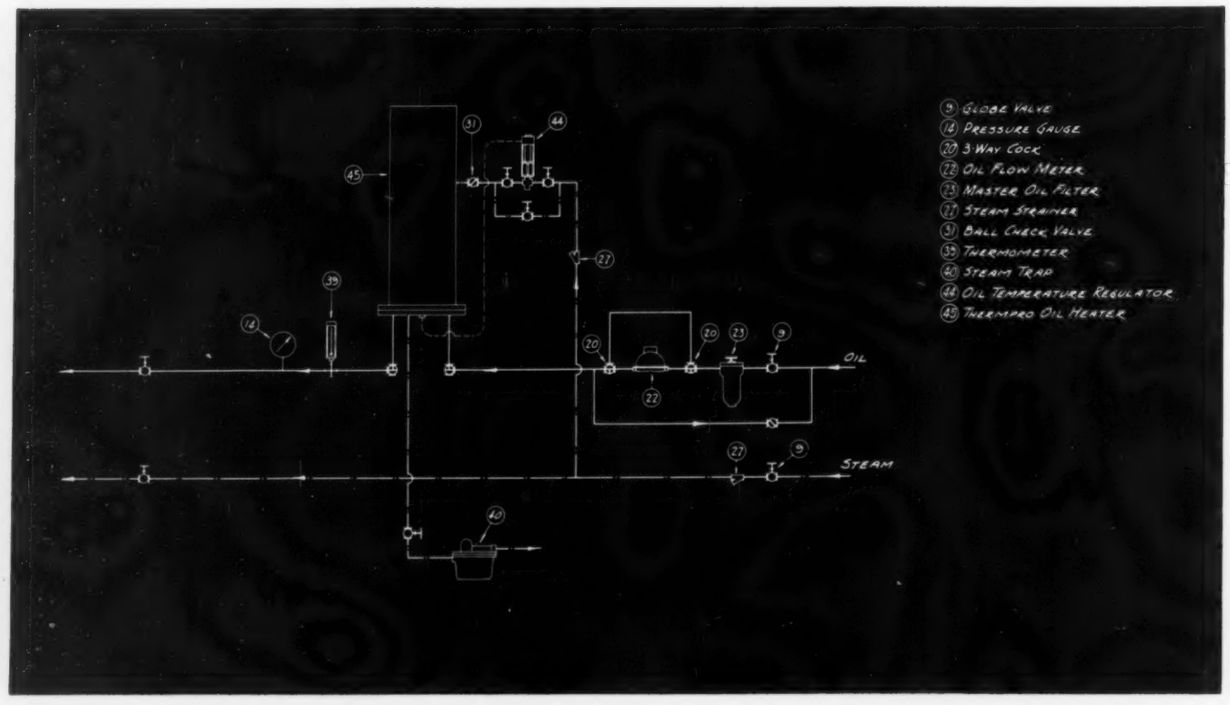
swing elbow in the pipe layout and by the adjustable slide between the butterfly and the burner body.

Maximum ranges of 10 to 30 gallons of oil per hour can be delivered with this burner.

The body of the burner in Fig. 11 is the same as the burner in Figure 10. The atomizer is different. Oil passes through the orifice hole and strikes a pin at right angles to the oil stream. The sudden release of pressure of the heated oil, 225 degrees F., causes the oil to foam. The oil foam passes out through the small tube to the end of the burner tip where it is carried into the furnace by means of a fixed primary converging air stream. The secondary air stream is also converging and is regulated by means of sliding the oil feed pipe in or out to create an annular opening between the atomizer and the burner nose.

The long flame of this burner may be used to recirculate the furnace gases. This increases the heating rate, and reduces the high localized flame temperatures usually found in oil firing.

FIGURE 22—Fuel oil conditioning system without booster pumps.



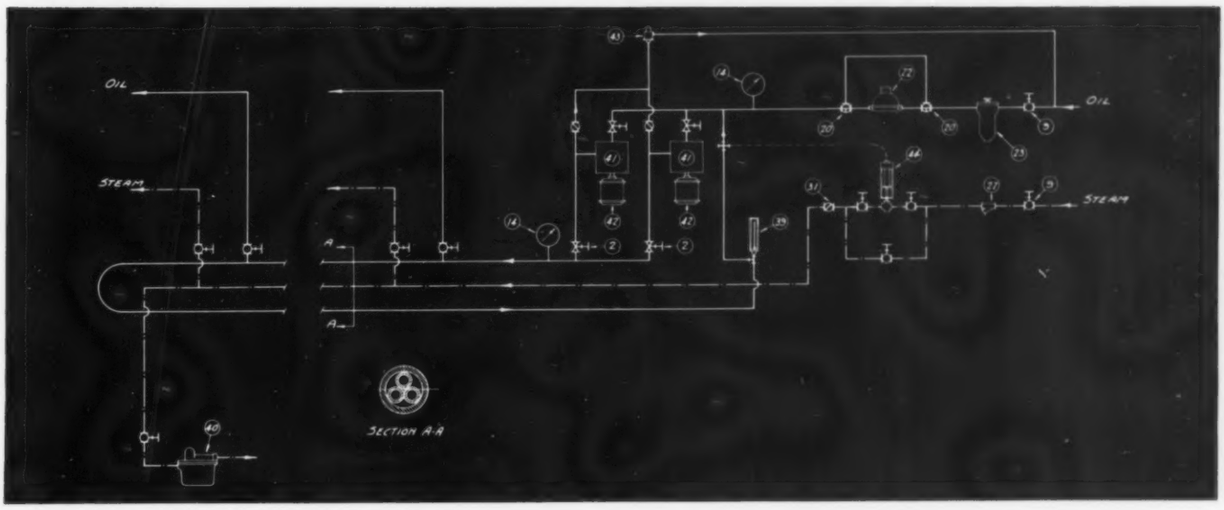
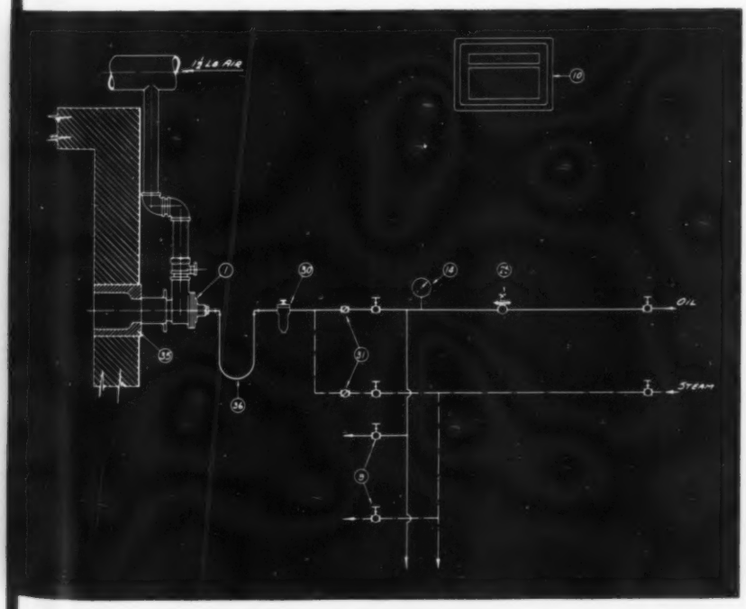


FIGURE 23—Recirculating fuel oil installation used in a wide-spread system.

Maximum flows of 10 to 30 gallons of oil per hour can be burned with this arrangement.

Fig. 12 is the same as Figure 10 except a diaphragm and spring assembly is attached to the oil feed pipe at the back of the burner. The diaphragm chamber is connected by radially drilled holes to the main oil stream. The diaphragm, therefore, assumes a position against the spring proportional to the oil pressure, thereby moving the atomizer shell at the nose of the burner which regulates the annular air stream for combustion.

FIGURE 24—Diagram of manual control application to furnace.



This arrangement does not proportion the oil and air in exact amounts but is sufficiently accurate for all indirect firing such as box annealing, galvanizing pots, lead pans, etc.

The maximum capacity of this burner is from 10 to 30 gallons of oil per hour.

Fig. 13 has the same atomizer as Figure 11, and the same diaphragm and spring assembly as Figure 12.

The burner in Fig. 14 uses air at 6″ of water pressure, oil at 20 lb., and steam at 15 lb. The body arrangement is the same as Figure 10. Steam and oil are mixed at the inlet of the oil pipe and sprayed out at the desired angle at the atomizer end of the same pipe. Short and long flames may be produced by changing the design of the atomizer. Air is regulated by the butterfly valve.

This burner is adapted for low rates of oil, 0 to 10 gallons per hour, and is used in small furnaces requiring clear atmospheres free from carbon particles.

Fig. 15 is a water cooled mechanical atomizing oil burner. It is particularly designed for roof firing.

The atomizer is housed in a water cooled shell so that the tip will stay cool regardless of whether oil is flowing or not. Oil enters the atomizer at a maximum of 200 lb. pressure and 225 degrees F. The design of the atomizer is such that the oil sprays out at any desired angle.

This type of burner is used generally with regenerative or recuperative furnaces.

A maximum of 30 gallons of oil may be used on this burner.

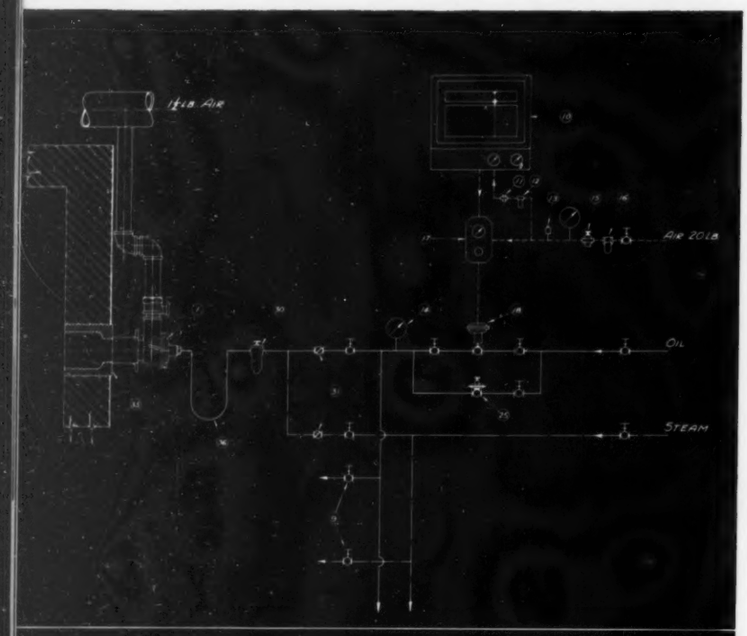
The burner in Fig. 16 is similar to Figure 15 except that a plurality of atomizers is used. They number either 2, 3, or 4, and they can be arranged according to the furnace requirements.

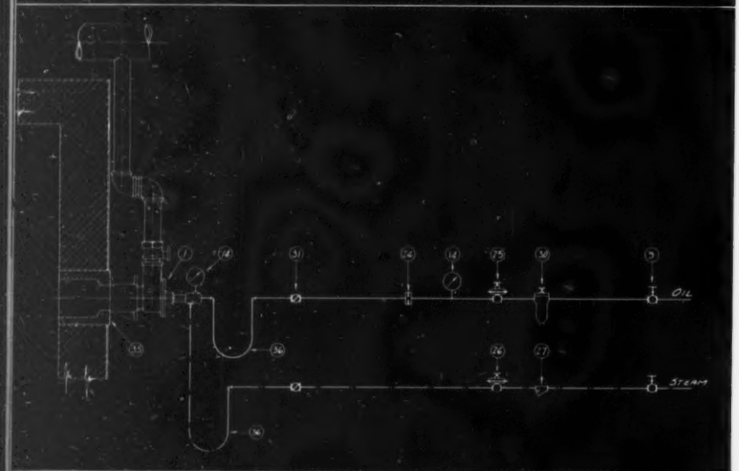
The object of using several atomizers is to get good atomization and turn down from a single source.

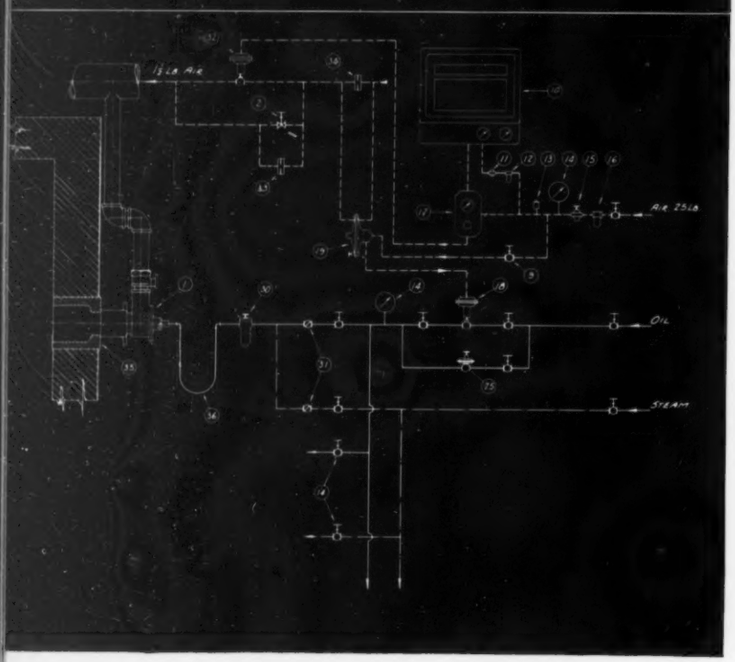
The burner has a maximum of 120 gallons per hour capacity.

The mixer in Fig. 17 is designed to mix a maximum of 10 to 600 gallons of oil per hour with sufficient steam to combine with the oil to make the desired flame luminosity.

This type of mixer uses the cyclonic principle of mixing. The steam and oil are thoroughly mixed, thus







eliminating any chance for stratified layers of oil and steam.

The burner tips may be either of the long flame or short flame type as desired, and they may be either air cooled or water cooled.

Figure 18 is the same as Figure 17, except it has a distribution head, whereby any number of outlets up to 12 may be used.

The mixer is particularly desirable where a number of adjacent burners are required operating in parallel.

The mixer is of most value on furnaces where automatic control is desired, since all the oil is controlled to the mixer and the mixer distributes same in equal amounts to the various burners. Each burner outlet is controlled by a flow control valve so that it may be adjusted in relation to the other burners to take more or less than the prorated amount of mixed steam and oil.

The burner tips may be one of several kinds as required by the furnace; long or short flame, air cooled or water cooled.

OIL CONDITIONING SYSTEMS

The conditioning of fuel oil is a most important item. The oil should be delivered to the burner in a heated state preferably 225 degrees to 250 degrees F. Figure 19 shows the temperature viscosity relations of Bunker C fuel oil. Note that the viscosity curve flattens out after 210 degrees F. is reached.

The oil should be free of all foreign or solid particles and should be strained through a motor driven continuous strainer or passed through a mill which breaks all the particles into very small pieces.

Figure 20 shows a layout of a central station oil system in which the oil is unloaded into a tank from cars or tankers. The oil in the tank is kept at approximately 140 degrees F. As the oil leaves the tank it is strained, metered, boosted, and heated. The oil lines are wrapped with a steam line in order to prevent cooling through the shop, mill, or plant.

If the central station is very large the oil heaters should be omitted and small ones placed at the individual furnaces.

The heaters are provided with three way inlet and outlet valves in order that the heater may be cleaned of coked carbon in position without taking it apart. This is done by circulating heated chemical solutions at high velocities through the heater.

Figure 21 shows a booster and heater system feeding off of a low pressure and low temperature system such as Figure 20. This system should be located at the furnace near the point of consumption.

A similar conditioning system but without booster pumps is shown by Figure 22.

FIGURE 25—(Top)—Air operated full floating control system.

FIGURE 26—(Center)—Hand control system for steam oil burner.

FIGURE 27—(Bottom)—Air operated full floating atmosphere control system.

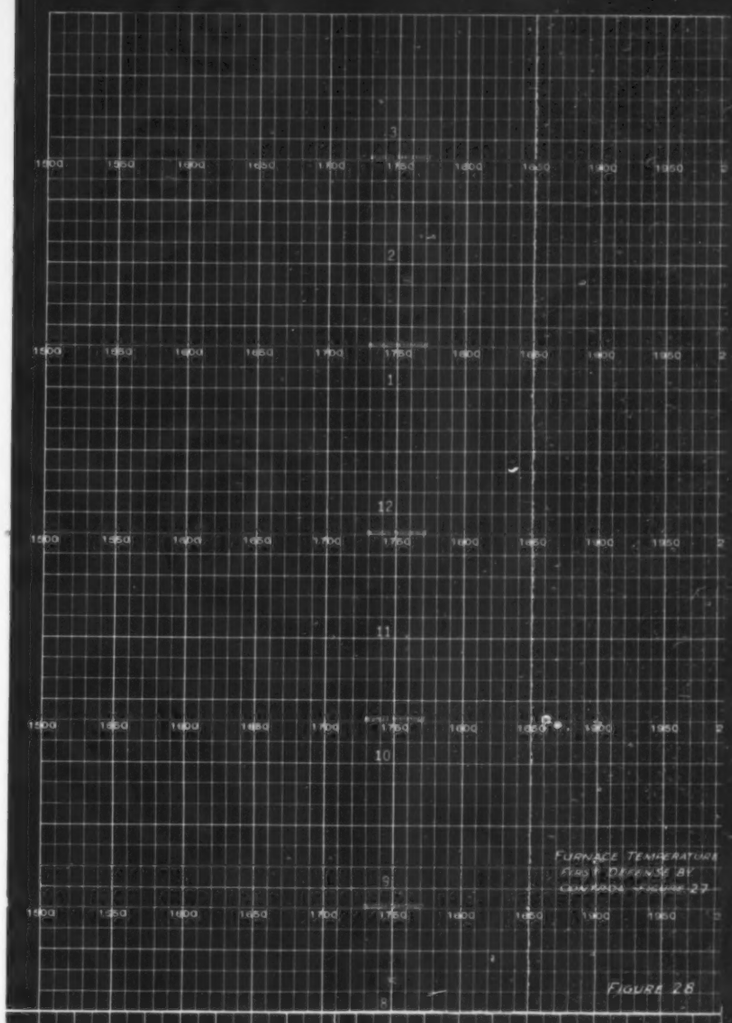
Figure 23 shows a recirculating oil system that is of considerable length such as may be used on unit air heaters in a large building. Here the oil heaters are

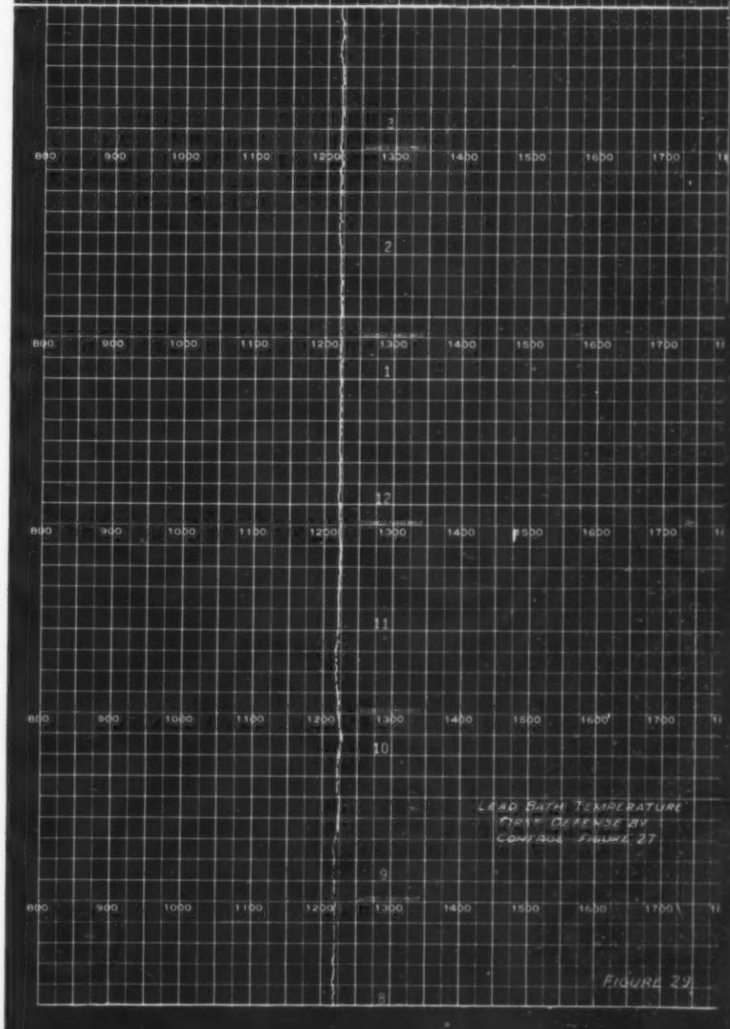
FIGURE 28—(Top)—Temperature chart from direct fired annealing furnace equipped with full control.

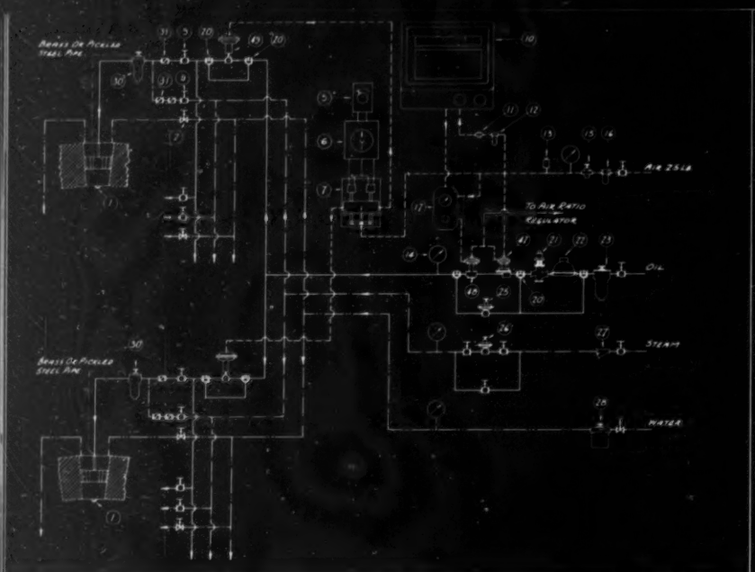
FIGURE 29—(Below)—Temperature chart from lead pan with full control.

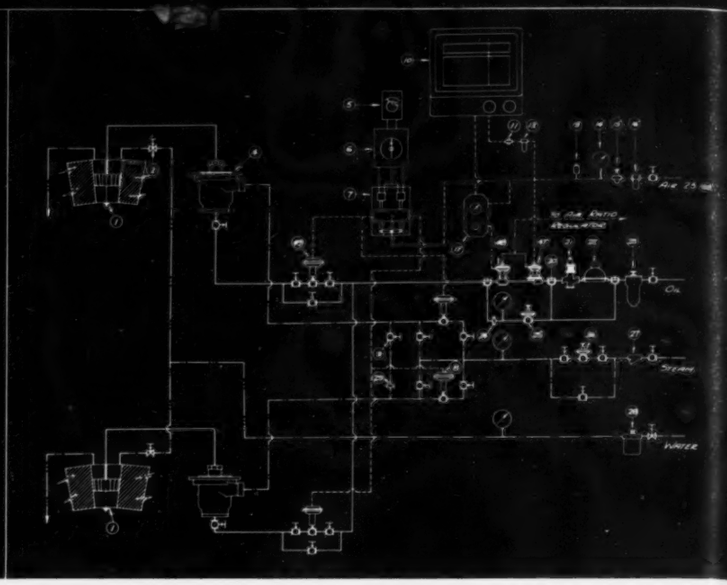
KEY TO CONTROL SYSTEMS

1. Burners.....Figures 10, 11, 12, 13, 14, 15 and 16
2. Gate Valve
3. Multi-Jet Steam Oil Mixer.....Figure 18
4. Single-Jet Steam Oil Mixer.....Figure 17
5. Manual Control Switch
6. Automatic Reverse Timer
7. Duplex Solenoid Valve
8. Air Operated Steam Valve.....Figure 9
9. Globe Valve
10. Potentiometer with Air Operated Control System.....Figure 2
11. Air Pressure Regulator
12. Drip Well
13. Air Relief Valve
14. Pressure Gauge
15. Master Air Pressure Regulator
16. Master Air Filter
17. Manual Control Panel
18. Automatic Oil Pressure Regulator.....Figure 6
19. Air Differential Static Converter.....Figure 4
20. Three-Way Cock
21. Area Type Flow Meter.....Figure 1
22. Oil Flow Meter
23. Master Oil Filter
24. Oil Orifice
25. Manual Oil Pressure Regulator
26. Manual Steam Pressure Regulator
27. Steam Strainers
28. Water Filter
29. Steam By-Pass Orifice
30. Fuel Oil Strainer.....Figure 8
31. Ball Check Valve
32. Air Operated Air Orifice.....Figure 9
33. By-Pass Air Orifice
34. Air Ratio Orifice
35. Flexible Metal Hose
36. Burner Tile
37. Fuel Oil Tank
38. Steam Coil
39. Thermometer
40. Steam Trap
41. Fuel Oil Pump
42. Oil Pump Motor
43. Oil Relief Valve
44. Oil Temperature Regulator
45. Oil Heater
46. Oil Regulating Relief Valve
47. Oil Differential Static Converter.....Figure 3
48. Automatic Oil Flow Regulator.....Figure 5
49. Air Operated Oil Valve.....Figure 9









eliminated and replaced by a steam line tightly wrapped along with the two oil lines. The self-acting regulator controls the oil temperature while the recirculating pumps keeps the temperature uniform throughout the system. The boost on these pumps is equivalent to the line loss in the oil lines, the initial pressure being furnished from the central station.

FIGURE 30—(Left, above)—Air operated control system with water-cooled mechanical burners, including automatic reversal and combustion control from temperature.

FIGURE 32—(Right, above)—A similar control system applied to single jet steam-oil mixers and water-cooled burners.

CONTROL SYSTEMS

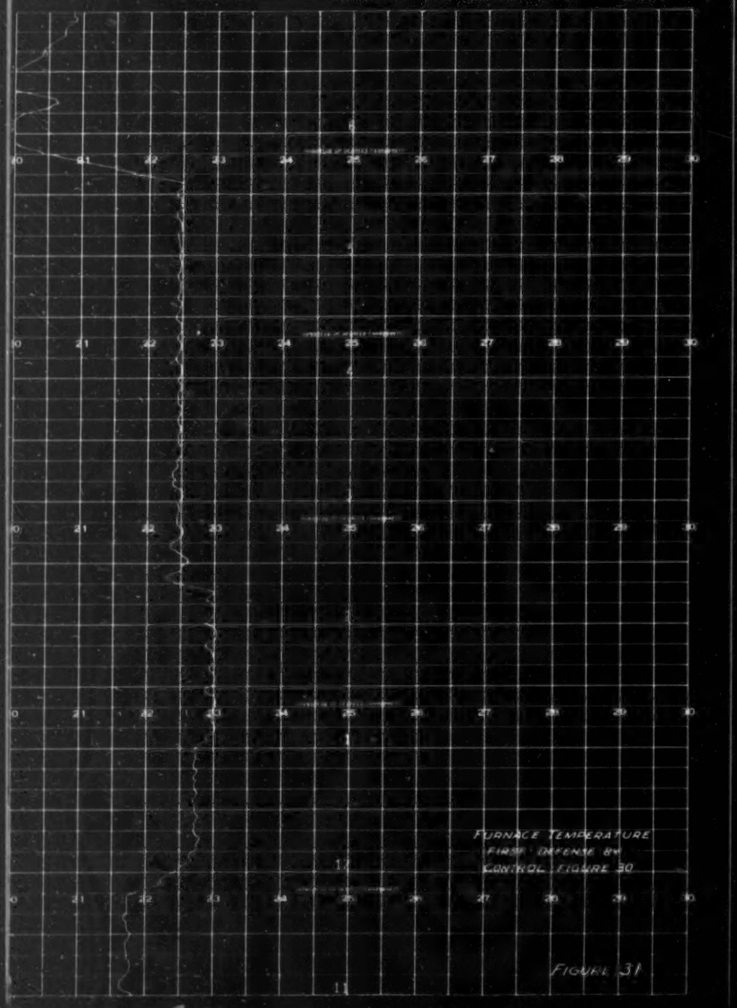
The key to the numbers shown on the control diagrams is the same as above:

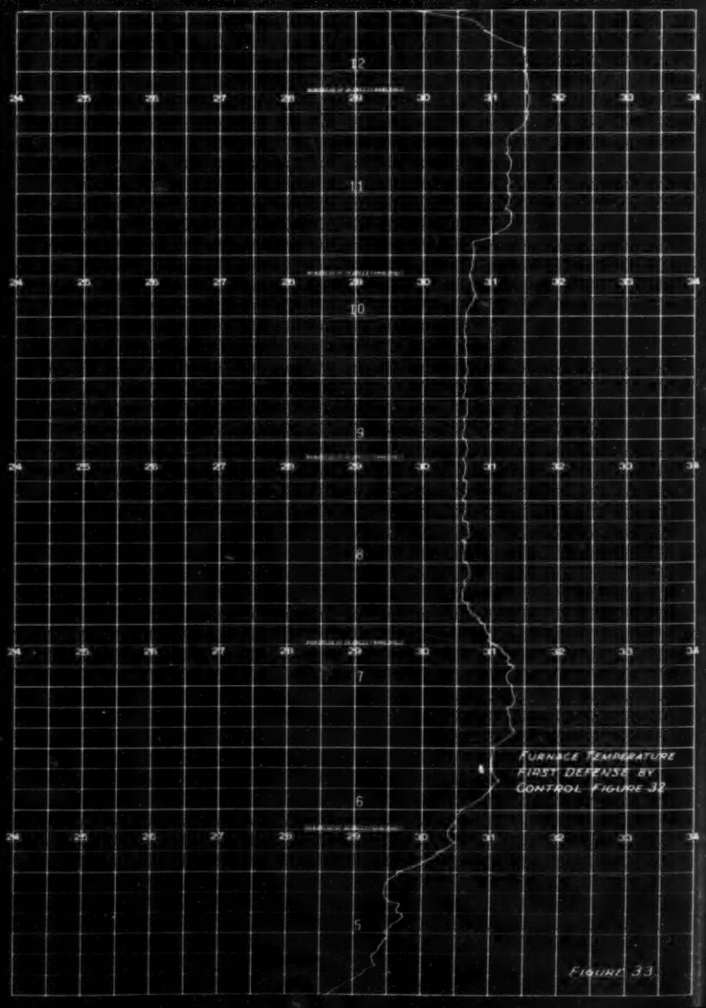
The burners in Figure 24 are those illustrated in Figures 10, 11, 12, and 13.

This system is generally used on small furnaces

FIGURE 31—(Left, below)—Temperature chart from a slab heating furnace using the control system of Figure 30.

FIGURE 33—(Right, below)—Temperature chart from open hearth furnace with potentiometer control.





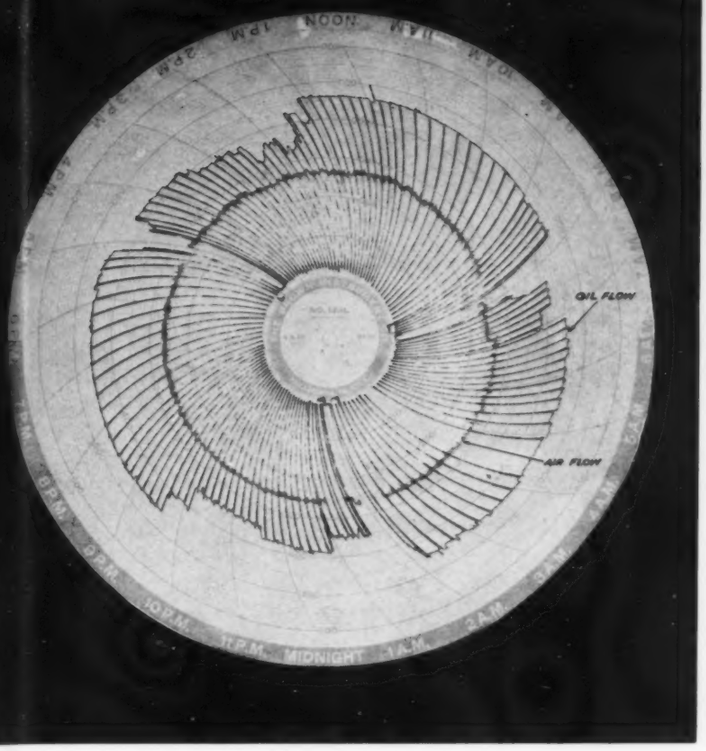


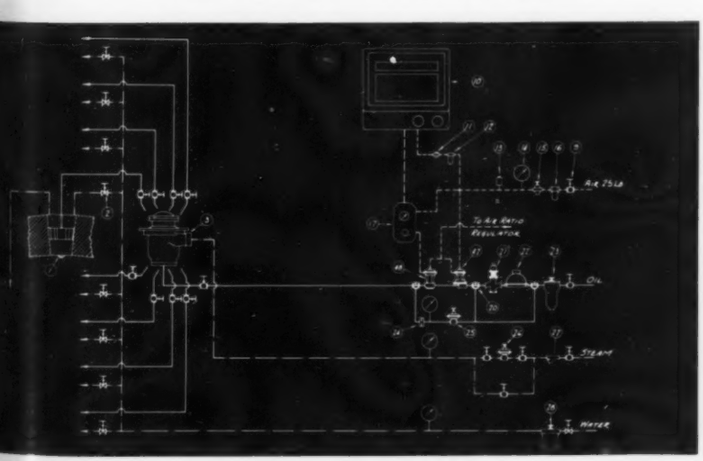
FIGURE 34—Oil flow chart from open hearth furnace on manual control.

where accurate temperature control is not desired or necessary.

The steam and oil lines are provided with check valves, No. 31, to prevent flow from one line into the other. The steam is used to heat the oil line and burner before starting and to blow same out just after shutting down. Steam is not used during the operation of the burner.

The pressure regulating method through the proper strainers guarantees the constancy of the oil flow rate. The oil orifice is in the atomizer of the burner. A set uniform oil flow has been the most difficult item to

FIGURE 35—Air operated system, with automatic combustion control operated from temperature, used with steam-oil mixers and water cooled burners.



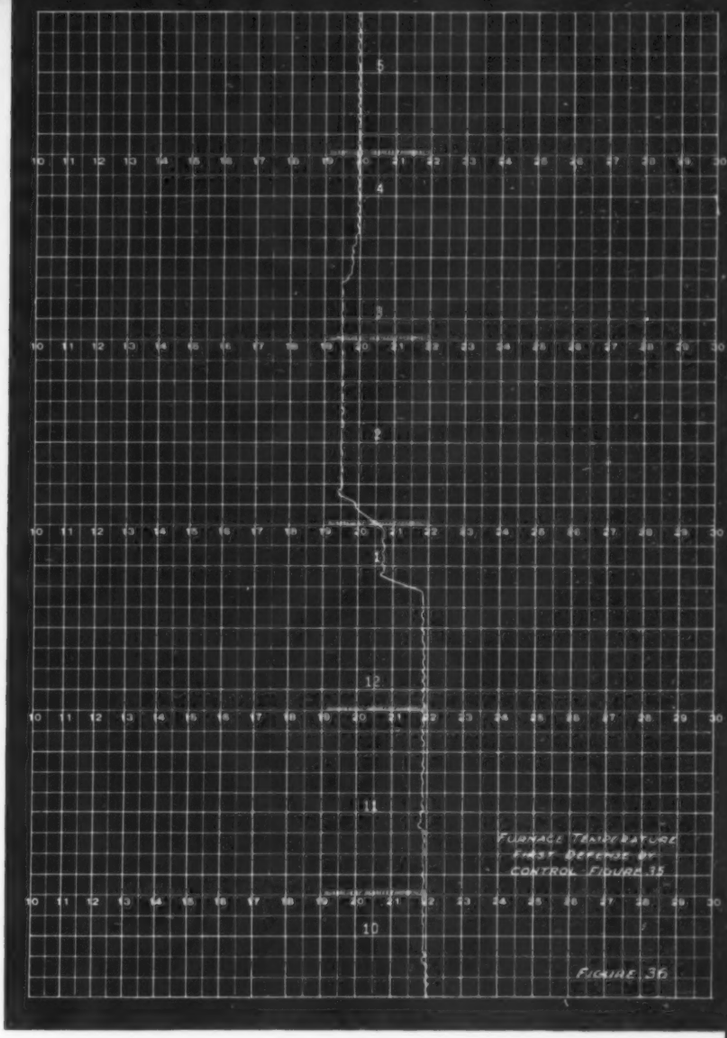
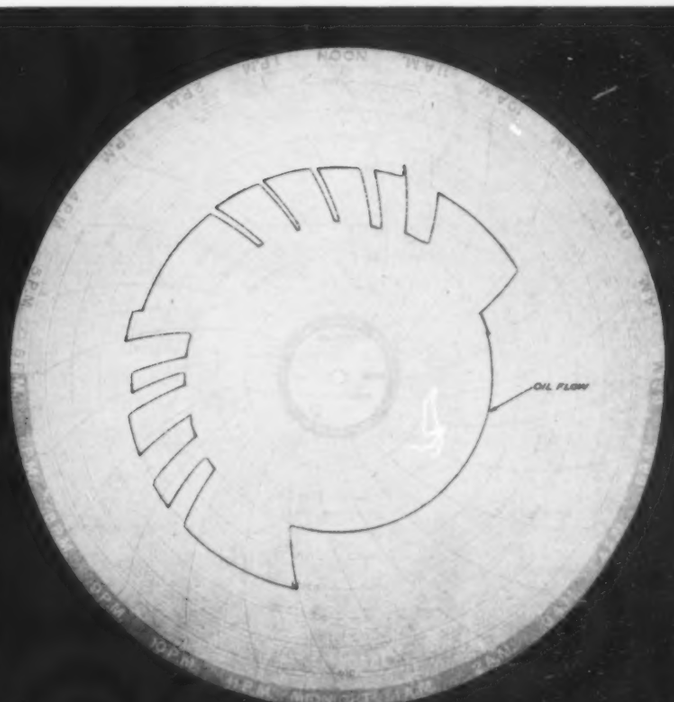


FIGURE 36—Temperature record of billet heating furnace with control system of Figure 35.

FIGURE 37—Oil flow chart from billet heating furnace.



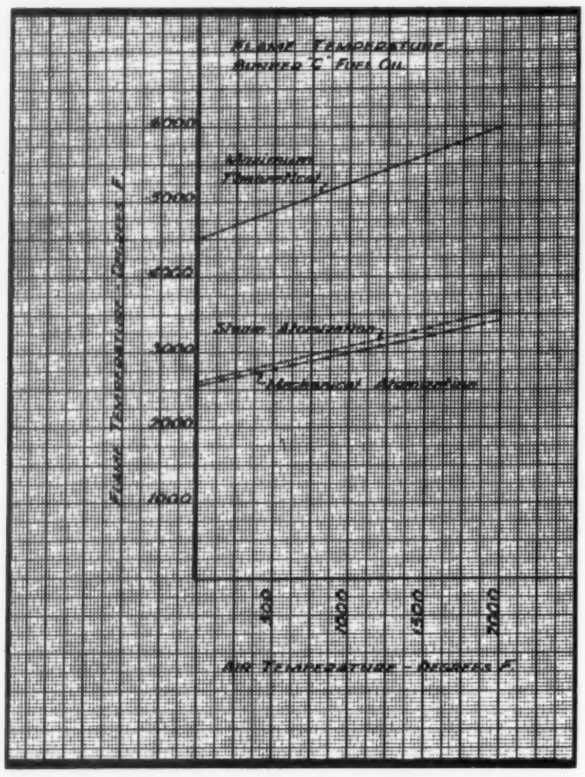
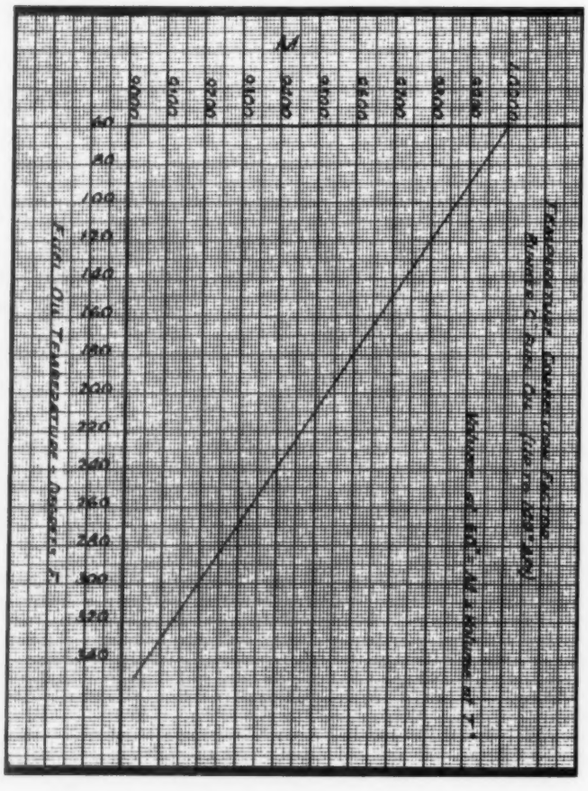


FIGURE 38—(Above)—Chart showing oil flame temperatures under various conditions.

FIGURE 39—(Below)—Chart giving temperature correction factors for Bunker C fuel oil.



attain in the burning of fuel oil. This method has solved that problem.

One or more burners may be operated in parallel from the same oil control set up. The air would then be controlled from a master air valve.

The oil burners used in Figure 25 are those shown in Figures 12 and 13.

This system is used where accurate temperature control is desired but where some leeway in atmospheric control is allowable. The potentiometer may be by-passed by means of the manual control panel, No. 17, which in turn may be by-passed and the system operated by hand by means of the manual oil pressure regulator, No. 25. The system therefore, has three defenses.

The burner for Figure 26 is the same as shown on Figure 14.

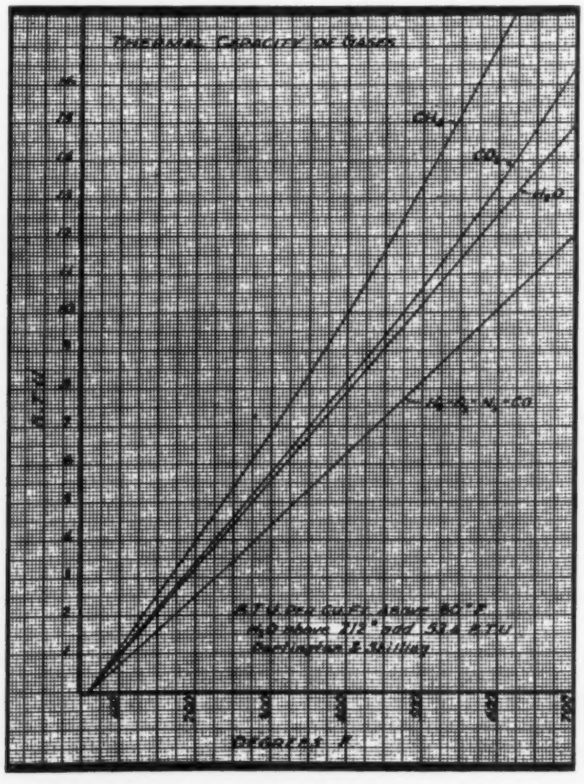
This system is used where exact temperatures and atmospheres are relatively unimportant. It is designed to give continuous operation with very little attention. Its particular use is on heaters, ovens, dryers, etc.

Figures 10 and 11 show the oil burners used on the system shown in Figure 27.

This control set up is for furnaces where accurate temperature and atmospheric control is required.

Any number of burners may be operated in parallel in the same zone of any furnace. The temperature is recorded and controlled from the potentiometer, and the atmosphere is controlled by regulating the by-pass valve on the differential static converter, No. 19.

FIGURE 40—Thermal content of various gases with varying temperatures (low temperature range).



The system has three control defenses, automatic, hand remote, and hand.

The furnace temperature may be controlled to plus or minus 2 degrees F. with constant atmosphere as shown on the chart in Figure 28. This chart was made on a direct fired annealing furnace. Figure 29 shows a chart made on a lead pan with the same system. This is a difficult job to control because of the temperature lag caused by the body of lead.

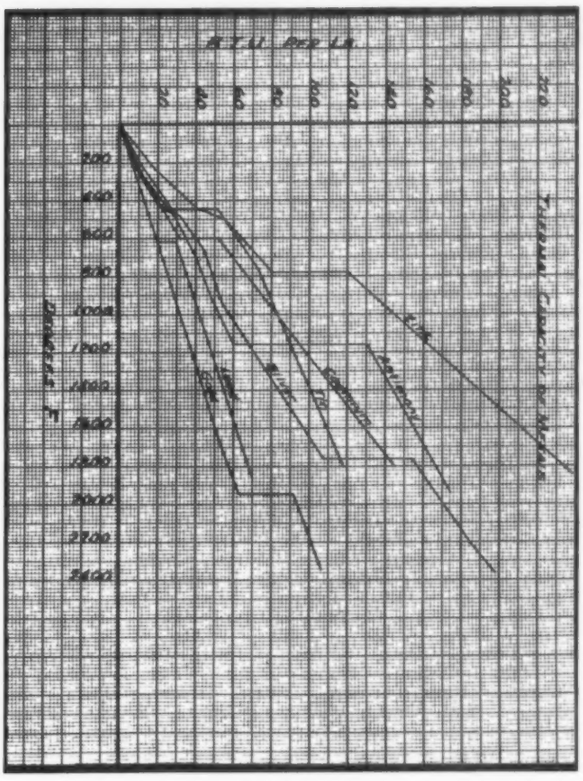
The oil burners used on Figure 30 are shown on Figure 15 and 16.

The system may be used on soaking pits and regenerative heating furnaces of all kinds. It is complete and automatically takes care of all factors requiring control. It has three defenses on the automatic reverse and an equal number on the control from temperature thus eliminating any possible furnace delays from failure of the equipment until repairs can be made.

Steam at about 15 lb. is controlled by the manual steam pressure regulator No. 26. By means of the check valves in the oil and steam lines, the steam flows to either end of the furnace alternating with the oil. This keeps the lines hot and the burners clean during reversals. The small amount of steam used is negligible.

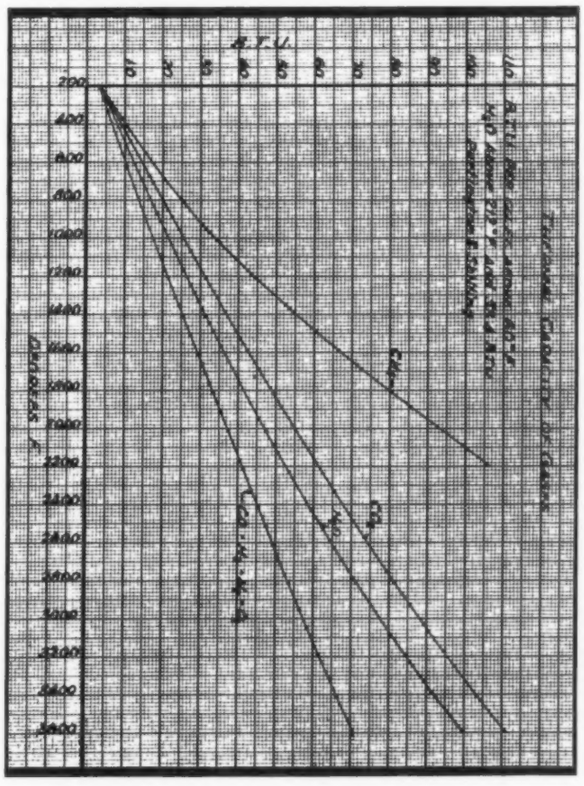
Control for continuous recuperative furnaces may be had by eliminating the reversing equipment shown on this figure.

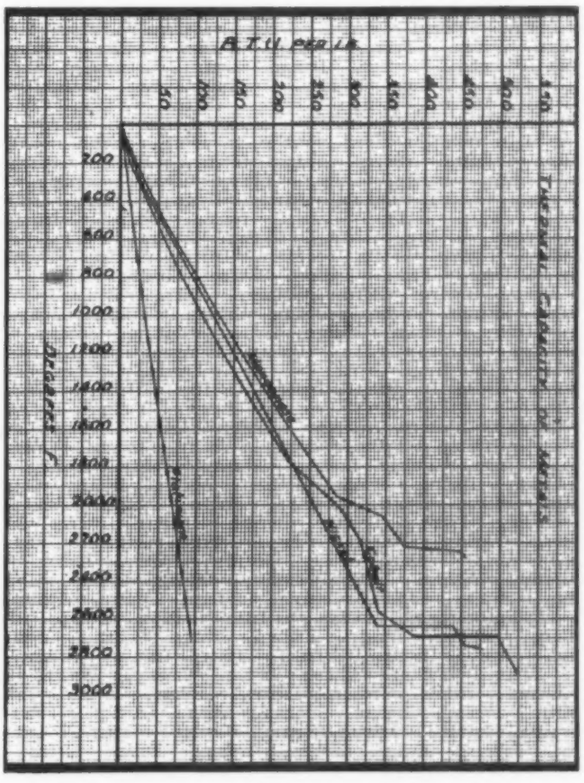
A temperature chart made by this system on a slab reheating furnace is shown on Figure 31.



FIGURES 42 and 43—Thermal capacities of various metals at elevated temperatures.

FIGURE 41—Thermal content of various gases with varying temperatures (high temperature range).





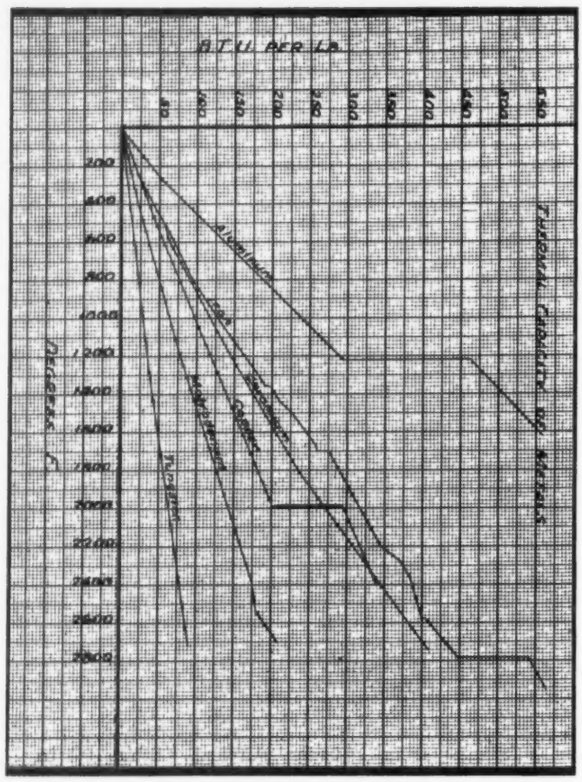


FIGURE 44—Thermal capacity of various metals at elevated temperatures.

The oil mixers of Figure 32 are shown in Figure 17 and the burners are the same as shown in Figures 15 and 16 except the atomizers are larger to pass the mixture of steam and oil.

A globe valve No. 9 and a steam by-pass orifice, No. 29 is used to keep the alternate oil burners hot during reversal periods.

The system may be generally used on furnaces requiring large volumes of oil at a single source with long narrow flames of high velocity.

The automatic reverse and temperature controls has three defenses.

Figure 33 illustrates the temperature record made by the first defense, air operated potentiometer No. 10. Figure 34 shows an oil flow chart made on this system by the second defense, manual control panel No. 17. Both of these records were made on open hearth furnaces.

The steam oil mixers in Figure 35 are shown in Figure 18 and the burners in Figures 15 and 16.

FIGURE 45—Thermal capacity of various refractory materials.

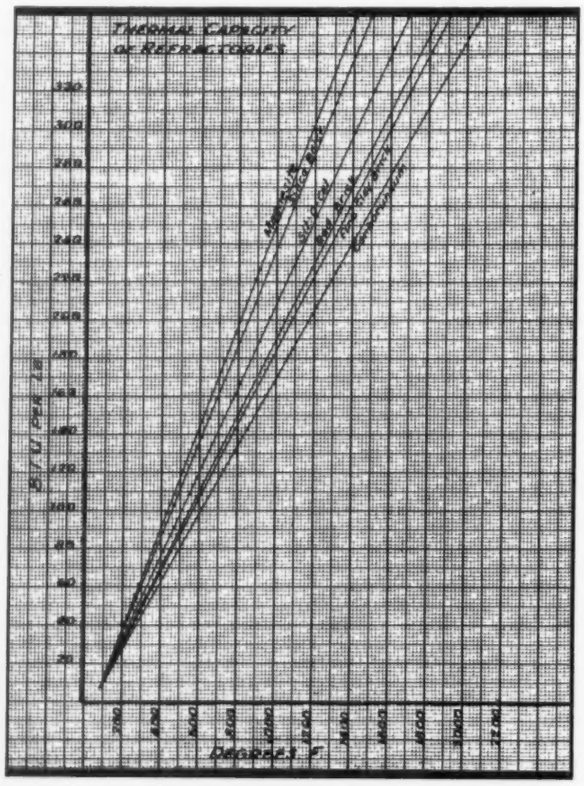
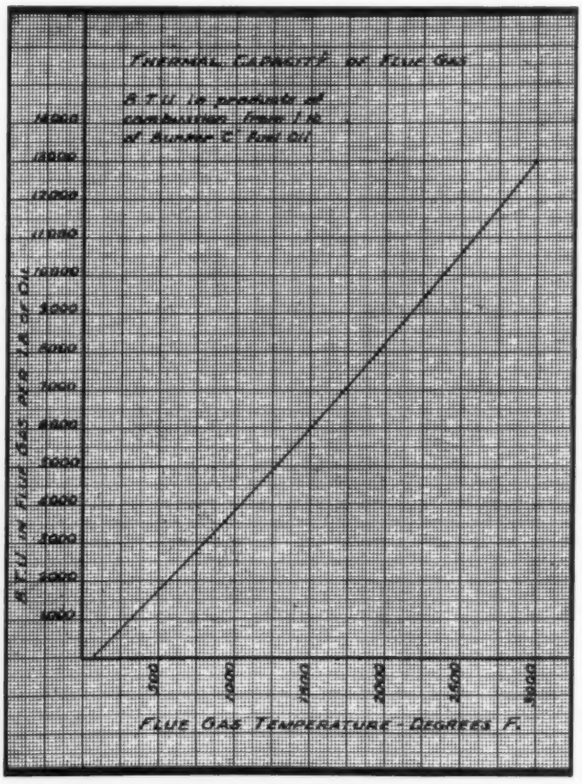


FIGURE 46—Thermal capacity of flue gas from combustion of one pound of heavy fuel oil.


Thermal Capacity of Flue Gas
B.T.U. in products of combustion from 1 lb. of Number 6 Fuel Oil
B.T.U. in Flue Gas per Lb. of Oil
Flue Gas Temperature Degrees F.

The system as shown is for continuous furnaces of from 2 to 12 burners.

Automatic reverse can be added similar to the controls shown on Figure 30 and 32.

The temperature control as shown has three defenses, automatic from temperature, remote hand, and hand control.

The system is particularly adapted to continuous zone firing on large furnaces where the total fuel input must be regulated accurately and the distribution of fuels to the various burners must be equal.

Figure 36 shows the temperature record made on a large billet heating furnace by this control layout. Figure 37 illustrates the oil flow made by the second defense, manual control panel No. 17.

COMBUSTION DATA

The theoretical and actual flame temperature for mechanical and steam atomization with the different air temperatures are shown on Figure 38.

The straight mechanical flame is very luminous and burns in the same manner as a rich gas. Its best use is on regenerative reheating furnaces where the air temperature is 1500 degrees to 2000 degrees F.

The steam atomized flame has less luminosity than the mechanical flame because the hydrocarbon particles of the oil are reduced to CO and H_2 by the steam which in turn burn to CO_2 and H_2O; both colorless reactions. Varying amounts of steam may be used, depending on the furnace temperature and the degree in which the oil and steam is mixed and atomized, which will affect the luminosity of the flame. The steam atomized flame gives rapid combustion in a contracted flame volume which explains the higher actual flame temperatures.

The furnace volume necessary for the complete burning of fuel oil should not be less than one cubic foot per 35,000 Btu. liberated per hour.

The following heat balance is taken from a billet heating furnace with an air heater or recuperator. The method of calculating the heat balance is shown in

MAXIMUM AVERAGE HEATING RATES OF OIL FIRED FURNACES

Kind of Heating	Control Figure	Sq. Ft. of Hearth Area	Max. Gal. Oil Per Hr.	Gal. Oil Per Hr. Per Sq. Ft. Hearth	Temp. Heated to From Cold	Lbs. Steel Per Hr. Per Sq. Ft. Hearth
Melting—open hearth	32	830	450	.543	2950	42.90
Melting—Open hearth	32	884	450	.510	2950	45.70
Slab reheating for plates	30	418	170	.406	2300	42.50**
Slab reheating for plates	30*	300	120	.400	2300	34.40**
Slab reheating for plates	30*	300	120	.400	2300	28.00**
Flanging for heads	24	82	30	.375	1500	4.98
Flanging for heads	24	320	120	.375	1500	8.88
Billet reheating for bar and rods	35	1500	450	.300	2300	76.16
Patent annealing wire	27	250	25	.100	1850	13.60
Slab reheating for hot strip	35	1435	600	.417	2300	70.80
Slab reheating for sheets	30*	245	90	.367	2300	30.60
Pair reheating for sheets	27	522	75	.144	1450	30.10
Pair reheating for sheets	24	76	30	.393	1450	65.00
Box annealing sheets	24	159	70	.444	1300	8.37
Box annealing sheets	24	210	55	.262	1100	11.65

*Automatic reverse with hand operated oil and air control.
**50 per cent Hot Steel at 1200 degrees F.

Kind of Heating	Sq. Ft. of Control Figure	Exposed Surface To Fire	Max. Gal. Oil Per Hr.	Gal. Oil/ Hr./Sq. Ft. Surface	Temp. of Bath	Lbs. Steel/ Hr./Sq. Ft. Surface
Lead anneal. wire	27	168	25	.149	1350	17.3
Galvanizing wire	27	131	20	.153	830	58.2
Galvanizing pipe	24	138	70	.507	825	130.0
Caustic soda wire	24	67	6	.089	1250	25.5

detail and may be used as a guide or reference in making heat balances of all types of oil fired furnaces.

1. DATA DETERMINED BY TESTS

Item (a)—Fuel Oil Analysis and Data

	Per Cent Weight
C	81.50
H_2	10.00
Combined N_2 and O_2	7.90
S	0.55
H_2O	0.05
Btu. per lb. at 60 degrees F.	18,800
Pounds per gallon	8.2

Fuel input 525 gallons per hour at 165 degrees F.
Atomizing steam input 1,312.5 lbs. per hour at 150 lb. gauge and 100 degrees superheat.

Item (b)—Air for Combustion

Air temperature entering recuperator:
Dry bulb.....85 degrees F.
Wet bulb.....72 degrees F.
Relative humidity from psychometric chart, 53 per cent.
Air temperature leaving recuperator....475 degrees F.

Item (c)—Flue Gases

Gases analyzed by the orsat are on the *dry basis.*

	Percent by Volume Leaving Furnace	Leaving Recuperator
CO_2	14.8	14.1
O_2	1.9	2.9
N_2	83.3	83.0
Flue gas temperature	1225 deg. F.	825 deg. F.

Item (d)—Cooling Water

Pounds per hour	77,500
Inlet temperature	65 degrees F.
Outlet temperature	113 degrees F.

Item (e)—Steel

Pounds per hour	123,200
Inlet temperature	85 degrees F.
Outlet temperature	2250 degrees F.

2. HEAT BALANCE CALCULATIONS

Item (f)—Input—Fuel oil heat of combustion.

Gal. of oil at 165 degrees (Item a) x Temp. correction factor Figure 39 = Gals. of oil at 60 degrees F.

or, 525 x 0.965 = 507

Gal of oil at 60 degrees F. x Btu. per lb. (Item a) x Lbs. per gal. (Item a) = Btu. per hr.

or, 507 x 18,800 x 8.2 = 78,159,120

Item (g)—Input—Sensible heat in the fuel oil.

Gals. per hour (Item f) x Temp. rise (Item a) x Specific heat Btu. per lb. per degree F. x Lbs. per gal. (Item a) = Btu. per hr.

or, 507 x (165 deg.–60 deg.) x 0.41 x 8.2 = 178,976

Item (h)—Input—Sensible heat in the air.

$$\frac{\text{Lbs. of carbon per lb. of oil (Item a)}}{\text{Lbs. of carbon per mol of carbon}} = \text{Mols of carbon per lb. of oil.}$$

or, $\frac{.815}{12} = 0.0679$

$$\frac{\text{Mols. of carbon per lb. of oil} \times \text{Lbs. of oil per gal. (from Item A)} \times \text{Cu. ft. per mol. at 60 deg. F.}}{\text{Mols of carbon per mol of flue gas leaving the furnace—(Item c)}} = \text{Cu. ft of dry flue gas per gal. oil at 60 deg. F.}$$

or, $\frac{0.0679 \times 8.2 \times 380}{0.148} = 1430$

$$\frac{\text{Cu. ft. dry flue gas per gal. of oil at 60 degrees F.} \times \text{N}_2\text{ in the flue gas analysis leaving the furnace (Item c)} \times \text{Gals. oil per hr. (Item f)}}{\text{Cu. ft. } N_2 \text{ per cu. ft. of air.}} = \text{Cu. ft. of dry air per hr. at 60 degrees F.}$$

or, $\frac{1430 \times 0.833 \times 507}{0.79} = 764,472$

or, $764,472 \times \frac{(460 + 85)}{(460 + 60)} = 801,167$ Cu. ft. of dry air per hr. at 85 deg.F.

From psychrometric chart, one cu. ft. of air at 85 degrees F. and 53 per cent relative humidity contains 6.8 grains of water per cu. ft.

$$\frac{\text{Cu. ft. of dry air per hr. at 85 degrees F.} \times \text{Grains of water vapor per cu. ft. at 85 degrees F. and 53 per cent relative humidity.}}{\text{Grains per lb.}} = \text{Lbs. of water vapor per hr.}$$

or, $\frac{801,167 \times 6.8}{7,000} = 778$

1 Cu. ft. of water vapor at 60 deg. F. = 0.04761 lbs.

Therefore, $\frac{778}{0.04761}$ = 16,341 Cu. ft. of water vapor per hr. at 60 degrees F.

	Cu. ft. per gal. of oil at 60 deg. F.		Btu. per cu. ft. at 475 degrees Fig. 40		Btu. per hr.
Dry Air	764,472	x	7.7	=	5,886,434
H_2O	16,341	x	63.1	=	1,031,117
			Total.....		6,917,551

Item (i)—Input—Sensible heat in the steam.

Item (a) and heat in the steam for atomization from the steam tables	Total heat 150 lbs. gauge 100 degrees F. superheat	Heat of liquid at 60 degrees F.
	1252.0	28.08

Total heat in steam above 60 degrees F.

1252.00 — 28.08 = 1223.92 Btu. per lb. of steam

Lbs. steam per hr. Item (a)		Btu. per lb. of steam		Btu. in steam per hour
or, 1312.5	x	1223.92	=	1,606,395

Item (j)—Output—Sensible heat in the steel. Item (e) and Figure 42

Sensible heat in steel at 2250° F.	=	360 Btu. per lb.
Sensible heat in steel at 85° F.	=	7 Btu. per lb.
Total.....	=	353 Btu. per lb. net output

Btu. per lb. net output		Pounds of steel per hour Item (e)		Total Btu. per hour
or, 353	x	123,200	=	43,489,600

Item (k)—Output—Sensible heat in cooling water. Item (d) and Steam Tables

Sensible heat in water at 113° F.	=	80.93
Sensible heat in water at 65° F.	=	33.07
Total.....	=	47.86 Btu. per lb. net output

Btu. per lb. net output		Pounds of water per hour Item (d)		Total Btu. per hour
or, 47.86	x	77,500	=	3,709,150 Btu. per hour

Item (l)—Output—Sensible heat in the flue gases.

$$\frac{\text{Mols of carbon per lb. of oil—Item (h)} \times \text{Lbs. of oil per gallon Item (a)} \times \text{Cu. ft. per mol at 60 deg. F.}}{\text{Mols of carbon per mol of dry flue gas leaving the recuperator—Item (c)}} = \text{Cu. ft. dry flue gas per gallon of oil at 60 deg. F.}$$

or, $\frac{0.0679 \times 8.2 \times 380}{0.141} = 1500$

$$\frac{\text{Lbs. of hydrogen per lb. of oil Item (a)} \times \text{Lbs. of oil per gal. Item (a)} \times \text{Cu. ft. per mol at 60 deg. F.}}{\text{Lbs. hydrogen per mol of hydrogen}} = \text{Cu. ft. of water vapor from the fuel oil per gal. of oil at 60 deg. F.}$$

or, $\frac{0.10 \times 8.2 \times 380}{2} = 156$.....156

$$\frac{\text{Cu. ft. of water vapor per hour in the air—Item (h)}}{\text{Gal. of oil per hour at 60 degrees F.—Item (f)}} = \text{Cu. ft. of water vapor from the air per gal. of oil at 60 degrees F.}$$

or, $\frac{16,341}{507} = 32$.....32

$$\frac{\text{Lbs. of steam per hr. Item (a)}}{\text{Gals. of oil per hour Item (f)} \times \text{Lbs. per cu. ft. of water vapor at 60 degrees F. Item (h)}} = \text{Cu. ft. of water vapor from atomizing steam per gal. of oil at 60 degrees F.}$$

or, $\frac{1312.5}{507 \times 0.04761} = 54$.....54

Total..... 242

Cu. ft. of dry flue gases per gal. of oil at 60 degrees F.		Flue gas analysis leaving the recuperator Item (c)		Cu. ft. per gal. of oil at 60 degrees F.
1500	x	0.141 — CO_2	=	212
1500	x	0.029 — O_2	=	44
1500	x	0.830 — N_2	=	1245
		H_2O	=	242

	Cu.ft.per gal. of oil at 60 deg. F.		Gal of oil per hr. at 60 deg. F. Item (f)		Btu.per cu.ft. at 825 deg. Figure 41		Btu. per hour
O_2+N_2	1289	x	507	x	14.0	=	9,149,322
CO_2	212	x	507	x	21.0	=	2,257,164
H_2O	242	x	507	x	70.9	=	8,699,005
					Total.....	=	20,105,491

3. HEAT BALANCE—SUMMARY

Input	Btu. per hour	Percent
Heat of combustion in the fuel oil	78,159,120	89.98
Sensible heat in the fuel oil	178,976	0.20
Sensible heat in the air	6,917,551	7.96
Sensible heat in the steam	1,606,395	1.86
Total	86,862,042	100.00
Output	**Btu. per hour**	**Percent**
Sensible heat in the steel	43,489,600	50.07
Sensible heat in the cooling water	3,709,150	4.26
Sensible heat in the flue gases	20,105,491	23.15
Radiation and unaccounted for	19,557,801	22.52
Total	86,862,042	100.00

DISCUSSION

PRESENTED BY

E. I. KRABER, Vice-President, York Oil Burner Co., York, Pennsylvania.

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O. F. CAMPBELL, Combustion Engineer, Sinclair Refining Co., East Chicago, Indiana.

F. E. LEAHY, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

E. C. MCDONALD, Combustion Engineer, Republic Steel Corporation, Cleveland, Ohio.

E. I. KRABER: I have enjoyed Mr. Fisher's paper on "Heavy Fuel Oil and Its Control", and he is to be commended on the very excellent presentation. Mr. Fisher referred briefly to air measurement or air control, in his paper, and I wish to contribute further by enlarging on this necessary phase in economical oil utilization.

For many years there has been a very distinct need for a device to properly and accurately control the flow of air or gas used for a variety of industrial purposes, particularly in the iron and steel industry.

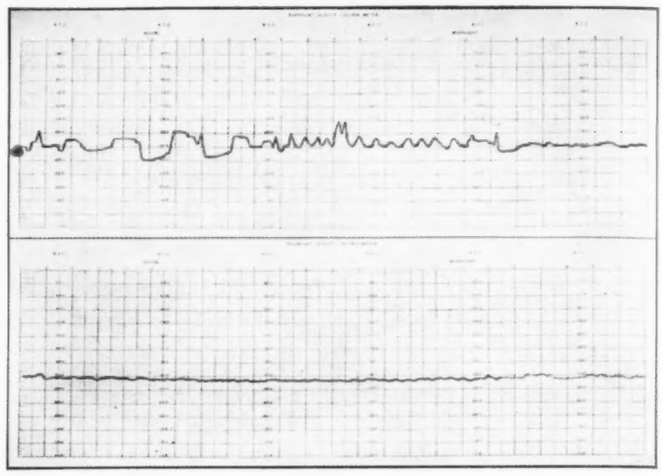


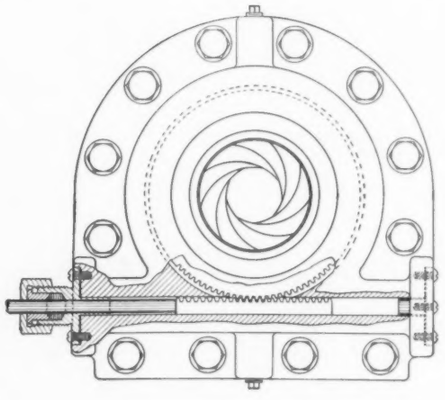
FIGURE 1

There have been many devices used in the past such as fixed orifices, gate valves, slide valves and butterfly valves; but such types are either not adjustable or they are not truly accurate.

The iris shutter regulating valve or variable orifice is the ultimate answer for any engineer or company who wishes to accurately control the flow of air or gas, for any purpose whatever within the usual limits of pressures, as used in gas and air distribution at the point of consumption in the industry.

Many, who have previously been skeptical as to the merits of the iris shutter regulating valve have, through application of it to their own particular problem, become convinced that it is the only method in existence that will produce such phenomenal accuracy. This is borne out by the following illustration (Figure 1). These charts were taken from the records of one of the largest steel mills in the country. One of the charts shows the best previous record over a number of years and the other is a record of the

FIGURE 2



performance obtained by the use of the iris shutter the first day it was in operation. This illustrates to you the ease and consistency with which it will maintain set temperatures by the correct proportioning of air, oil or gas.

Because of its unique design and careful manufacture, the slightest movement of the cam will change the setting (Figure 2). The fact that it will duplicate its setting is exceedingly valuable because, after the

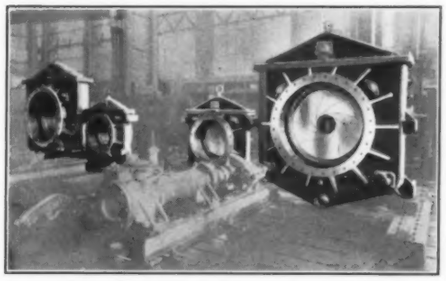


FIGURE 3

operating characteristics of the furnace have been determined, the shutter can be set and the setting will be duplicated, no matter how many times it becomes necessary to change it. Because of this accuracy of resetting, it is a comparatively easy matter to tie in the shutter operation with that of liquid fuel.

Figure 3 illustrates a gas and air valve connected in tandem which, when connected to the proper selection of instruments, can produce a predetermined Btu. flow of fuel to the furnace.

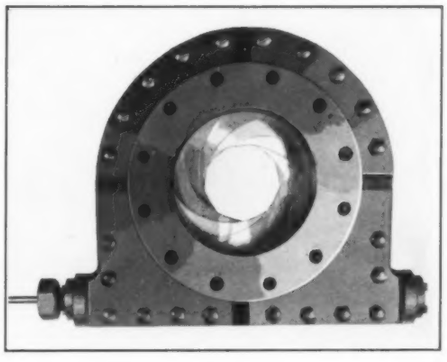


FIGURE 4

In the heat treating of steel and other metals, an iris shutter will maintain perfect regulation of the combination of fuel and air supply to the furnace.

One of the outstanding features of this valve is the elimination of the distorted flow of gas or air, as the orifice is always in the center of the pipe line or the point of discharge. This is particularly noticeable when the valve is located close to the point where the gas is discharged into the furnace and is partly responsible for the very close accuracy in the adjustment and duplication of gas and air mixture.

The actuating mechanism on the shutter can be either electrical or mechanical. This particular construction (Figure 4) is adaptable to operation with air or oil. Two valves of this type, one for gas and the other for air, can be connected up with a link and lever so that one piston will operate both valves, synchronizing them perfectly.

The most popular method seems to be that of electrical operation (Figure 5). In this type a small motor control unit is built into the valve casing and a rheostat is mounted on the rear of the shutter dial. Another manual adjusting dial, having a rheostat with the same graduations, is located at the point of control. By moving the dial to the desired point of open-

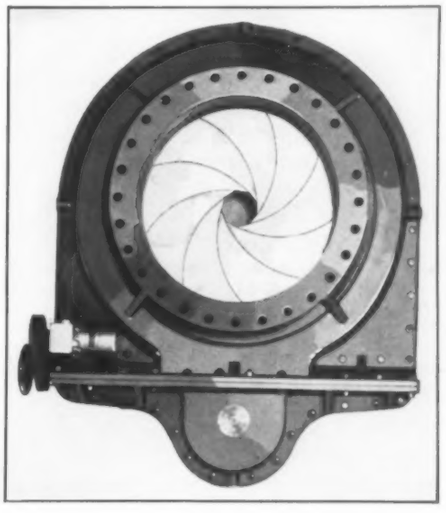


FIGURE 5

ing, the motor will open or close the valve to the exact setting required.

The iris shutter, as has been outlined, for controlling both air and gas to the various types of furnaces, has also been applied to mixing stations. At present, one of the large steel plants has a system whereby they are mixing producer and coke oven gas. This system has proven highly successful in its operation. This plant has four iris shutter valves—two on the producer and two on the coke oven gas lines. One is used primarily to control the pressure and the other to control the volume. The control system is such that it is very responsive. Any change in the Btu. value of the individual gas, which would affect the Btu. value of the mixed gas, is immediately transferred to the control plant. There it synchronizes the valve action to compensate for this Btu. change, thus delivering a mixed gas of constant Btu. value.

In the few minutes I still have at my disposal I will show you a few slides illustrating the use of the iris

shutter on the air supply to a low pressure oil burning system.

This will be of particular interest to you because it is installed on a regenerative soaking pit which has been converted from producer gas to oil firing with remarkable results, both in quality of heating and cost of operation.

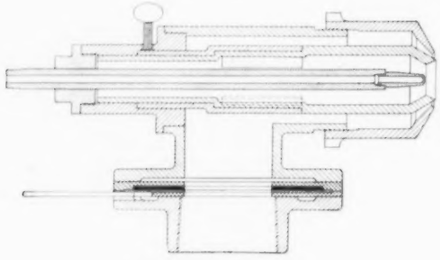


FIGURE 6

The burner used (Figure 6) is known as our wide range low pressure burner. The oil nozzle is adjustable and can be moved in or out as desired. The inner air barrel is stationary and has a sleeve on the outside which can be rotated to increase or decrease the inner air stream. This air nose is threaded so that it can be adjusted to produce a long narrow flame or a wide short flame. This, in conjunction with the movable nozzle, produces a variety of flame characteristics to suit any requirement or any unusual condition. You will also note in the illustration of this low pressure burner that the iris shutter is closely coupled to the burner, and we have found this method of installation very effective in maintaining uniform, atomizing air velocities at all positions of the shutter orifice.

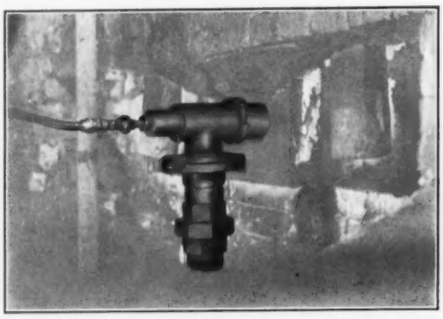


FIGURE 7

The condition to which I refer is that the velocity of the air passing through the shutter remains constant regardless of how far the shutter is opened or closed. The iris shutter is capable of a large range of adjustment on the quantity of air that passes through it. This, together with the barrel adjustment, air nose adjustment and oil nozzle movement, makes possible perfect control of flame. By varying the quantity of oil through the several adjustments mentioned, it is easy to fire over various widths of checkers and length of ports.

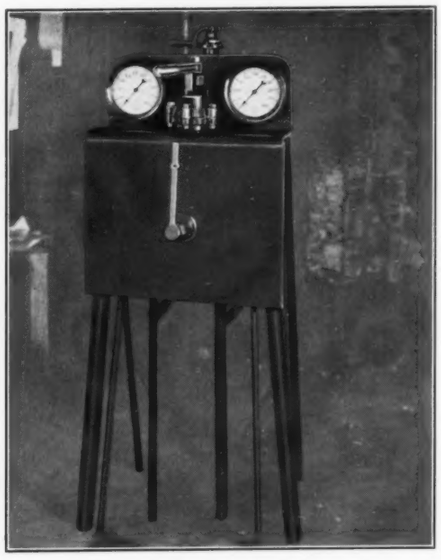


FIGURE 8

Figure 7 shows the manner in which burner is connected to the soaking pit previously mentioned. This is the ordinarily constructed regenerative type of furnace. Two wide range, low pressure burners are located on opposite sides of the soaking pit.

FIGURE 9

From the control stand (Figure 8) located on top of pit, at a point convenient to operator, oil lines are run to both burners. An oil regulating valve with graduated scale is mounted on this stand and is connected to a three way valve, so that oil supply can be changed from one burner to the other.

The air supply, which in this case is a low pressure

fan set, is located in passageway beside soaking pit, directly under control stand.

Two iris shutter valves (Figure 9) with lever action, are located in the air line which goes from the fan set to the burner. These are mounted directly under control stand so that the valves can be operated by a lever from this stand. They are so connected that, when one valve is open, the other is closed to a point that will allow only sufficient air to pass out, on the waste gas side, necessary to keep burner cool. This air supply is changed from one burner to the other in the reversing action of furnace.

Burners are equipped with the proper type of nozzles to meet the desired requirements, and their supply is synchronized with the oil regulating valve on the control stand. Other adjustments, such as iris shutter, regulating valve, air barrel adjustment, air nose adjustment and oil nozzle movement can be made on the burners. After the necessary adjustments have been made and the required type of operation is obtained, it is only necessary to operate the levers on the control stand and the burners will continue to operate as originally set.

M. J. CONWAY: Mr. Fisher, as usual, has contributed generously. The problems of fuel oil control are somewhat complex. Fuel oil is the most concentrated form of fuel used, therefore a small volume wastage represents considerable fuel energy lost.

This is readily seen when you stop to consider that one cubic foot of fuel oil represent 1,125,000 Btu. or 11.25 therms, as against one cubic foot of natural gas containing 1150 Btu. or a one hundreth part of one therm. Fuel oil has a volume Btu. value 1000 times greater than natural gas, so that an error in control means much more with this concentrated fuel than it does with the less concentrated gaseous fuels. A lot more can and will be done to effectively handle these control problems which Mr. Fisher has told us about.

I wish also to contribute emphasis to that part of Mr. Fisher's paper dealing with furnace design. It is important to design the laboratory of the furnace around the fuel for the best results, but it is also necessary to give the same care to the calculation of fuel-air velocities, especially on furnaces operating at 2400 degrees F. and under.

It is also important to carefully regulate and keep constant the temperature and pressure of the fuel oil and the incoming air in order that the control apparatus can properly function.

The illustration shows a recent adaptation of fuel oil to regenerative soaking pits which is working successfully.

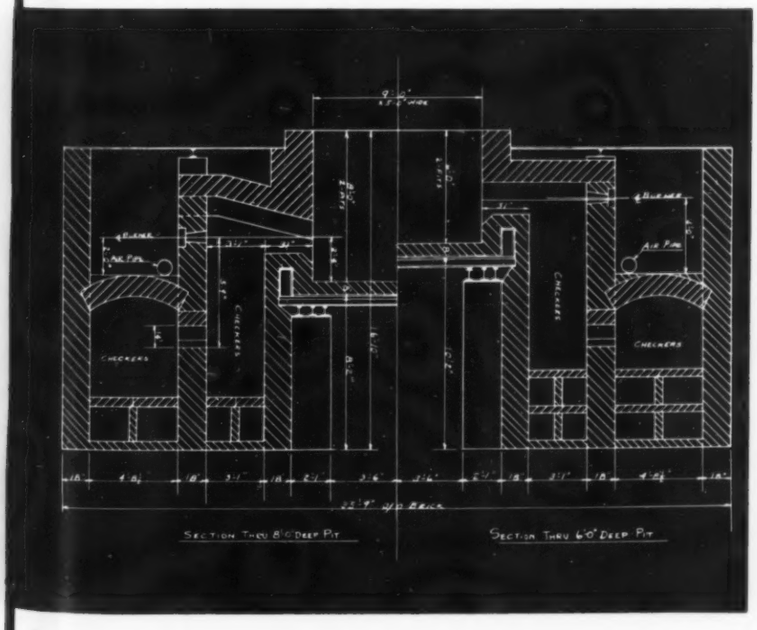
The fuel replaced was producer gas, which due to the heavy freight charges on the coal was costly. The fuel oil installation made the operation more economical from a fuel cost standpoint and has other obvious advantages, such as ease of fuel control, shorter light up time, etc.

O. F. CAMPBELL: Mr. Fisher has ably presented a brief history of fuel oil burning from its primitive state to its present automatic state. Mr. Fisher has painted a picture of an operator operating an open-hearth furnace with everything running smoothly, completely automatic, all controls in synchronism, furnace temperature being maintained by controlling oil flow to the furnace, and the furnace atmosphere maintained as desired. The operator in command of the open-hearth furnace has the choice of operating the unit completely automatic, semi-automatic, or by hand control. The above picture most assuredly denotes progress from the original primitive method of fuel oil firing.

It is felt that Mr. Fisher left out one very important point in his paper, as he did not tell what should be done or what would happen when the automatic controls fail. It is important to consider what should be done and what is likely to happen when the compressed air, steam, hydraulic liquid pressure, or electrical current fails for the control instrument. When the compressed air to an air-actuated instrument fails, and it does, what happens? To an operator of any fuel-burning equipment, be it large or small, it is always gratifying to know that when all the facilities of the automatic equipment fail he has some means of manual adjustment—"The Armstrong System". Mr. Fisher's paper did not reveal how the manual adjustment can be accomplished with the automatic equipment which he has so ably explained.

Automatic control is merely doing mechanically what can be done manually and if it can not be done manually it can not be done automatically. It appears that elaborate installations of automatic equipment, as outlined by Mr. Fisher, can in some cases be carried too far. It can readily be conceived that so much complicated automatic equipment can be installed that a corps of instrument men are necessary to keep the automatic equipment functioning. It might be advisable to use the instrument men for automatic

Sectional view through regenerative soaking pit to which fuel oil has been successfully applied.



control and eliminate the fixed charges and repairs. Automatic control, with its accompanying advantages must be used with judgment and discretion, taking into consideration fixed charges, maintenance, supervision, and depreciation. It is highly probable that in many cases automatic equipment has been operated out of adjustment and has caused an operating loss, as well as a loss in quality of the finished product.

The petroleum industry depends upon automatic control and a large number of operations are automatic and due to fire hazards, suitable precautions are usually made for manual operation when utilities for instruments fail. Automatic fuel oil firing for stills in refineries is not ordinarily used, but automatic gas firing is common. The modern refinery usually produces more than enough residue refinery gas to operate the stills and the surplus refinery gas and unmerchantable fuel oil are used for refinery boiler plant fuel. The modern combination unit in an oil refinery operates so uniformly that automatic gas firing is not absolutely necessary, as when operating under manual firing control the oil transfer temperatures can be maintained within a two-degree range over a period of twenty-four hours and automatic firing under these conditions does not appear particularly attractive. The refinery boiler plant, which consumes the surplus refinery gas, acid sludges, and unmerchantable fuel oil, is not susceptible to automatic firing. The unmerchantable fuel oil and acid sludge are not uniform in character and automatic firing with this type of fuel would not be successful.

Mr. Fisher has pointed out that it is his opinion that the most important element in the design of an oil-burning system is the furnace. I concur with Mr. Fisher in this statement, but do not believe that there should be any compromise between the requirements of the material to be heated and the oil-burning equipment. The oil-burning equipment should be of such design and flexibility as to satisfactorily heat the material to be heated regardless of shape, area, or volume of the combustion chamber. It appears to me that the job before us in the design of the oil-burning equipment to suit the furnace best suited for the products produced.

Mr. Fisher points out that oil burning has its limitations and, generally speaking, that fuel oil can best be used in large furnaces using considerable quantities of fuel oil. I disagree with Mr. Fisher in this regard. For the information of all concerned, fuel oil burners are now being used for automobile trailers and are of such magnitude as to consume only a few ounces of fuel oil per hour, and in the September issue of "Combustion" magazine there appears a picture of a mechanical-atomizing oil burner having the capacity of 8,000 pounds of fuel oil per burner per hour. It appears that the limitations of fuel-oil burning are of great magnitude and apparently the upper limit has not as yet been reached.

Mr. Fisher points out the difference between the actual and theoretical flame temperatures for mechanical and steam atomization with different preheated air temperatures and indicates that the actual flame temperatures are higher with steam atomization than with mechanical atomization. Theoretically, mechanical atomization should give a higher theoretical flame temperature than steam atomization and I believe that it will do so, provided the same degree of atomization and mixing of fuel and air are obtained. The steam used for atomization must of necessity lower the theoretical flame temperature, as the heat required to heat up the steam is not available for heating up the products of combustion to produce maximum theoretical flame temperature.

Mr. Fisher also points out that the mechanically-atomized oil flame is very luminous and burns in the same manner as a rich gas and that the steam-atomized oil flame is less luminous. The difference in flame characteristics and furnace temperature between mechanical atomization and steam atomization appears to lie in the degree of atomization and the air-fuel mixture. Steam atomization produces a finer break-up of the liquid fuel globules, thereby presenting a greater surface for oxidation and combustion is therefore more rapid. Steam and oil mixed intimately produces a froth or a foam and multiplies the oil film surfaces of the bubbles many-fold over mechanical atomization. This more efficient mixture of fuel and air with steam atomization will probably produce a higher flame temperature, as less excess air for combustion can be used on account of the more efficient air-fuel mixture.

It is possible to have a luminous or a non-luminous mechanically-atomized oil flame. The best illustration can be obtained by comparing the flame of an ordinary gun-type domestic oil burner, which produces a luminous flame, and a silent automatic domestic oil burner, which produces a non-luminous flame. The difference between these two flames lies in the thoroughness of the oil atomization and the thoroughness of the mixture of air and fuel oil. The above illustration indicates that steam is not necessary to produce a non-luminous oil flame.

I am certain that you will all agree with me that fuel oil can be burned only as fast as the air and the fuel can be intimately mixed and no faster. If the mixture is poor, combustion will be delayed and luminosity will result. The delayed combustion will produce long flames and it is possible that, due to the long flame, lower localized furnace temperatures may result. It does not appear that steam atomization has anything to do with luminosity or theoretical flame temperatures. It also does not appear that steam atomization reduces the particles of fuel oil to CO and hydrogen, which in turn burn to CO_2 and water vapor, which are substantially non-luminous reactions. It is questionable whether or not the steam has anything to do with the physicochemical complex compound C_x O_y, or whether steam has anything to do with the hydroxylation, or whatever the chemical reactions may be that take place when fuel oil is burned. Furthermore, hydrocarbons, especially the higher ones as found in heavy residual fuel oils, may decompose into carbon and hydrogen by cracking and this reaction is undoubtedly very rapid at the high temperatures usually encountered in the steel industry. Apparently there is a race between thermo-decomposition of the hydrocarbons and the process of hydroxylation. If conditions favor hydroxylation there should be no soot, however, if furnace conditions favor cracking, the hydrocarbon will decompose thermally into carbon

and hydrogen and will burn with a smoky or luminous flame.

It appears wrong to atomize fuel oil with steam when it can be done mechanically. The problem which confronts us is to intimately mix the air and the fuel oil, using mechanical atomization in order to produce a flame equivalent to or better than the steam-atomized oil flame. It is my opinion that this can be done.

The nature and source of the fuel oil also has something to do with the nature of the flame, as highly cracked residual fuels of low gravity contain less hydrogen and Btu. than uncracked fuels and are usually more difficult to burn. It has been my experience that a highly cracked residual fuel oil requires a better air-fuel mixture than a straight-run fuel oil of the same gravity and general specifications. I can not appreciate where Mr. Fisher obtained such a poor fuel oil, as shown by the ultimate fuel oil analysis he has presented. The U. S. Bureau of Standards, Department of Commerce, Miscellaneous Publication No. 97 shows a Btu. value per pound of fuel oil, ash, water, and sulphur free, of 18,600 for a fuel oil having a weight of 8.2 pounds per gallon. The fuel oil analysis given by Mr. Fisher does not check with the government information and numerous fuel oil analyses that I have seen. It appears there must have been an error in the recording of the ultimate analysis of the fuel oil shown by Mr. Fisher in his paper.

The oil refineries depend upon domestic consumers, tractor fuel, diesel fuel, range oils, etc., for the disposal of the lighter grades of domestic fuel oil and upon the steel industry as a major consumer of heavy residual fuel oils. The oil industry needs the help of the steel industry to dispose of its heavy residual fuel oils. There can be no doubt but that automatic fuel oil firing with all its advantages will stimulate the increased use of the real heavy residual fuel oil, which is one of the major products of the oil industry. The steel company gets more heat out of a barrel of heavy fuel oil than they can obtain from a barrel of light fuel oil. It is to the advantage of the oil industry to sell the heavy fuel oil and to the advantage of the steel industry to consume it. It appears to me that the slogan for both the oil and the steel industries should be "More automatic controls and more profit".

F. E. LEAHY: In listening to Mr. Campbell, I was very much interested in many of his statements, particularly about mechanical atomization. We have at various times attempted to use mechanical atomization in the open hearth furnace. We may not be aware of the proper technique, but the companies that have tried to do it for us have not been successful. This would make a remarkable change in operation, so that I was extremely interested. From what we have done to date, I believe that we, like Mr. Fisher, favor steam atomization.

There is another thing that is along the same line as Mr. Fisher's experience. Where do they make the dividing line between air atomization and steam atomization?

A. J. FISHER: Mr. Leahy, the steam atomization is usually used in melting furnaces and, as I said in my paper, on large furnaces where accurate temperature control is required. Small furnaces may use air atomization and mechanical atomization. The small burners shown in the paper are a combination of the two. On regenerative furnaces where the air is pre-heated and there is no chance to mix the oil and the air together mechanically, we favor mechanical atomization, but we have never been able to get any more than about thirty-two hundred degrees flame temperature under any conditions with mechanical atomization, and then only in spots. In steam atomization we have been able to get thirty-three hundred and thirty-three hundred and fifty degrees over large flame areas. That explains why you, in your tests, have found that you have never been able to use mechanical atomization successfully in the open hearth.

I might add that we have run the same experiments as Mr. Leahy. We have tried to do the job mechanically in the open hearth. We have spent considerable time and money and effort and did not get to first base. Theoretically it can be done, the difficulty being in the fact that the air and oil cannot be thoroughly mixed at the source.

E. C. MCDONALD: Mr. Fisher's paper has thoroughly covered the burning of fuel oil to my satisfaction with the exception of the viscosity at which oil should be burned. Mr. Fisher brought out the point that after the viscosity curve reaches the minimum the curve flattens out so that it is quite evident from his discussion the lowest viscosity is most satisfactory. I question that. I think there is a proper viscosity to burn each of the different grades of fuel oil but I do not believe it is the minimum as pointed out in the paper. I would like an answer to that.

Also, I would like to ask a question about burning a combination of fuel oil and coke oven gas. Mr. Fisher has probably had some experience along that line. When burning fuel oil with coke oven gas in the proportion of fifty percent of each should the aim be to keep the oil temperature at the maximum with lowest viscosity, or should the aim be to operate at some higher viscosity. When burning coke gas in an open hearth furnace luminosity is very desirable. I have found better results can be obtained by increasing the viscosity slightly when burning a combination of gas and oil.

A. J. FISHER: The reason we run the oil temperature above two hundred twenty-five or two hundred and fifty degrees is in order to get constant conditions so that the fuel oil can be controlled by a measuring device. Practically all of the controls I showed you here in the paper measure on an orifice method. Therefore, the viscosity of fuel must be constant, otherwise the control would not be accurate.

In regard to mixing or burning oil with gas, a good many different combinations come up. The subject is in itself a difficult one. There are so many ramifications to it that I purposely avoided it in this paper. As you refer to open hearth work, I believe that the colder the oil is the slower it burns and the more cracking you get with a higher flame luminosity. I doubt whether you can control the volume as accurately as you could if it were hotter. So in your case you would have to make a number of tests and compromise between the two.

FORGED *Steel* ROLLS

By J. R. ADAMS, Supt. Special Products

and H. L. WATSON, JR.

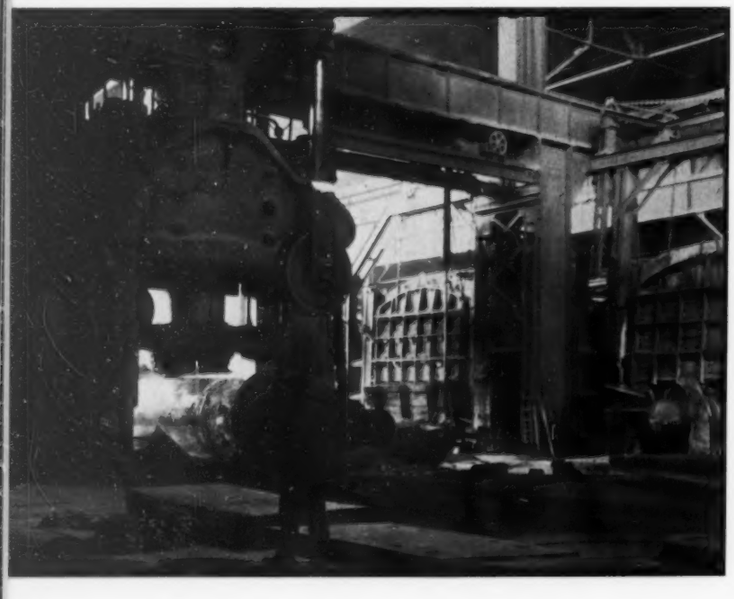
MIDVALE STEEL COMPANY

PHILADELPHIA, PENNA.

Presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Maryland, April 28 - 29, 1938

▲ THE steel for forged steel rolls is usually melted in an electric furnace or an acid open hearth furnace and cast in ingot moulds for subsequent forging. The ingot moulds are of the large-end-up type and of special shapes for the problem at hand and with ample hot tops. Moulds giving satisfactory ingots of normal structural alloy steels will not necessarily be successful for those steel rolls made from the higher carbon ranges of the compositions in common use. For these compositions it has been advisable to design special moulds. Likewise, temperatures and pouring speeds are different for these analyses.

FIGURE 2—View of 10,000 ton press with ingot being forged into a roll.



After pouring, ingots are allowed to remain in the moulds only long enough to be sure there is no liquid remaining, then stripped and charged while still hot into forging furnaces heated to approximately the same temperature as the ingots.

The precaution respecting the absence of any liquid in the interior of the ingot at the time of removal from the mould is especially important in the case of the higher carbon alloy analyses since any deficiency in the centers of ingots of these compositions is not corrected in subsequent forging.

Upon charging the ingots are heated to the temperature of the hot forging furnaces and cooled slowly until they have passed through the recalescence temperature. Heating of the ingots for forging starts at this point and proceeds on a rigid schedule that depends upon their composition, size, and shape.

The smaller rolls may be forged under the hammer but rolls finishing 8″ in diameter and larger are usually forged under a press. Since hardened steel roll compositions resist deformation in forging more than normal compositions, larger presses than usual are required for forgings of their size.

Best results are obtained with "V" dies. Every precaution to insure sound centers is taken. Neglect to do so will be responsible for breakage in subsequent hardening.

The completed forgings, while still hot, are charged into hot annealing furnaces, soaked out at the temperature of the furnaces, and cooled slowly until the forgings have passed through the recalescence temperature. The annealing treatments start at this point. These treatments consist of various normalizing and annealing heats depending upon the composition and size. For the smaller rolls two treatments may be enough, but for the largest rolls four to six heats are required. All heating is done and all cooling takes place in accordance with rates prescribed by schedules that have been determined by experiment and experience. This is very

FIGURE 1—Typical ingot used for the forging of steel rolls.

important since the steels used for rolls have low conductivities and the cross sections of the pieces being forged or heat treated are usually large. These two factors combined with improper rates of heating and cooling readily build up stresses that bring about internal ruptures which in some cases are not discovered until some time after they occur. The fracture shown in Figure No. 3 was caused by too rapid heating.

Upon completion of the annealing treatments, the rolls are preliminary turned and bored.

Although the previous treatments give the best possible annealed structure, further treatment before hardening is advisable. This treatment consists of various quenches and draws; the composition, size, and purpose of the rolls determining their selection. After this pre-hardening treatment, specimens are taken from the rolls for microscopic examination. If the structure is unsatisfactory, the treatment is repeated.

The rolls are now machined for hardening. Successful hardening is to a large extent dependent upon the elimination of sharp corners, thin sections, re-entrant angles, large changes in sections and deep grooves. In most cases hardened steel rolls have to be manufactured to designs furnished by the users or rolling mill manufacturers. When rolls are designed by users or rolling mill manufacturers in collaboration with roll producers best results are obtained and much subsequent grief both for the user and the manufacturer may be avoided.

Submission of tentative roll designs to roll manufacturers frequently results in the elimination of objectional hardening features and factors that will affect the subsequent life of the rolls in service without inconvenience to the users.

Rolls are hardened in various ways, depending upon

FIGURE 3—Fracture of a roll caused by too rapid heating in the annealing process.

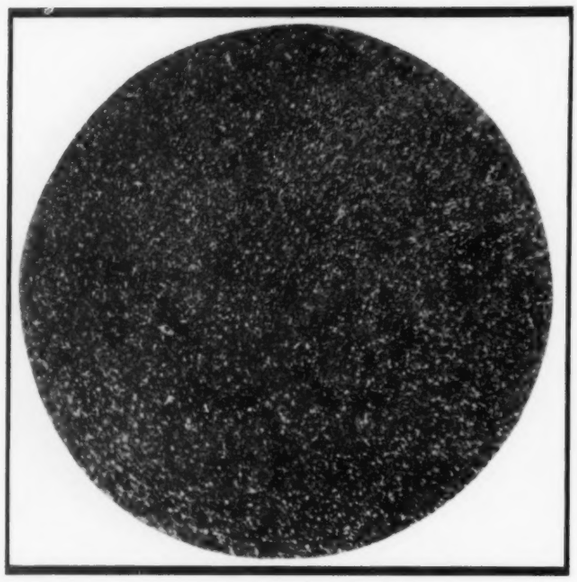


FIGURE 4—Structure of a roll at 100 diameters.

the compositions, hardness desired, and service. Furnaces used for the heating of rolls for hardening are of special design and are not normally used for any other purpose. All heating is done on schedules that have been worked out for the particular furnace and rolls being heated for hardening. The rate of heat input at various stages while the roll is coming up to the hardening temperature is important, likewise the furnace atmosphere.

Quenching is done in air, oil, water, or other solutions utilizing specially designed fixtures for the protection of journals, shoulders, wobbles, keyways, fillets, and chamfers, et cetera, during cooling. The hardest rolls are quenched in water or brine solutions, preferably by means of a spray.

After quenching rolls the hardening strains should be relieved whether the rolls weigh only a few pounds or 75,000 pounds. This is done by drawing in such a manner that the hardness is not reduced below the minimum required for the particular service the rolls will be required to give. The drawing or relief of hardening strains is done in air furnaces, oil baths, salt baths, electric furnaces, assisted in some cases by mechanical means.

FIGURE 5—Scleroscope as applied to hardness measurement on a roll.

FIGURE 6—View in a modern roll grinding shop.

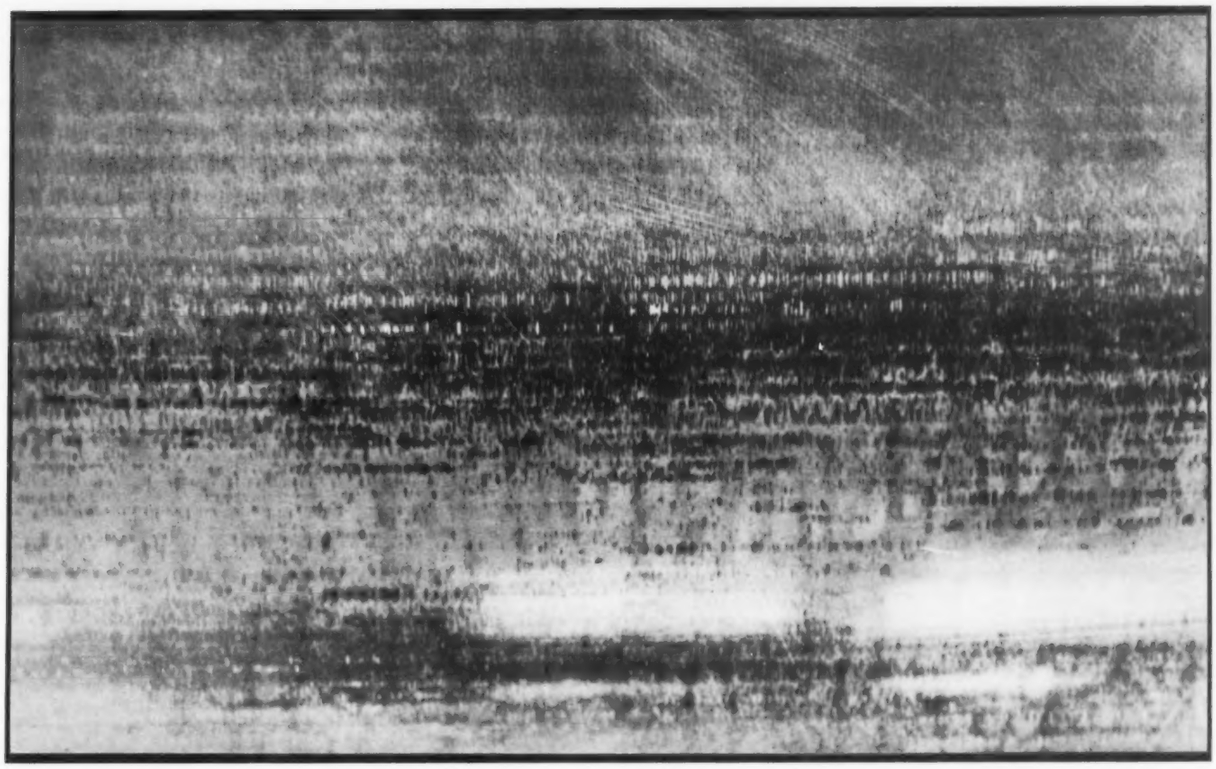
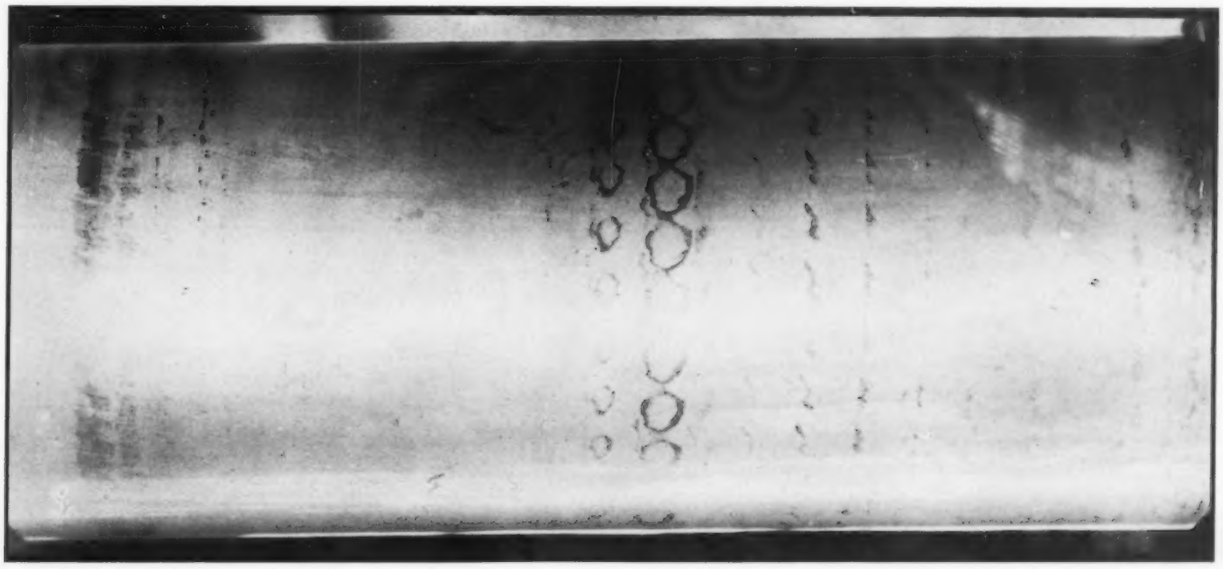


FIGURE 7—Grinding chatter burns the face of rolls (5 per cent nital etch).

When the quenching and drawing operations are completed the rolls are thoroughly tested for hardness. The hardness of smaller rolls may be determined by means of the scleroscope, Monotron, or Rockwell hardness tester. That of large rolls is universally determined by means of the scleroscope. Consistent and concordant readings are difficult to obtain between various scleroscopes. This is a cause of much vexation to both the roll manufacturers and the roll users. We endeavor to control this situation by using a specially designed stand to support the scleroscope on the rolls as shown in Figure No. 5, a uniformly prepared surface on which to determine the hardness, and by always placing the rolls on a firm, level foundation free from vibration.

The scleroscopes are always, before using, checked on the standard blocks supplied by the instrument manufacturer and on large standard blocks of the same cross section as medium sized rolls. The instruments

FIGURE 8—Another example of burn from chatter on roll face (5 per cent nital etch).



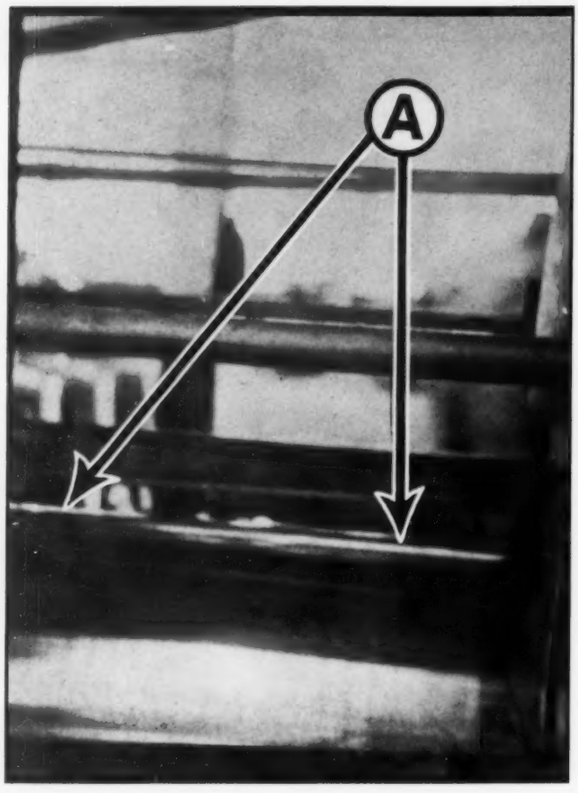
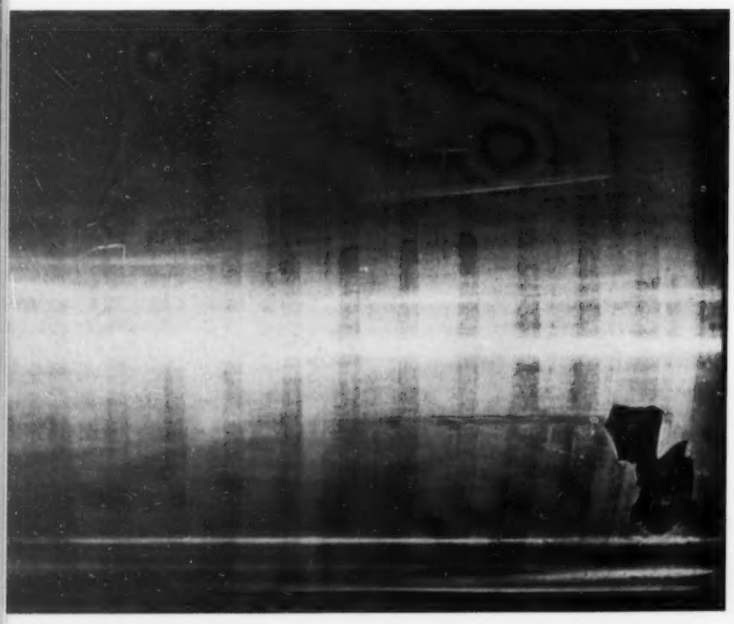


FIGURE 9—Faulty grinding produced these traverse marks on a roll in a mill.

are periodically returned to the manufacturer for cleaning, overhauling, and calibration on his standard blocks, and upon a standard 10″ diameter roll in his plant.

FIGURE 10—Traverse marks are often an indication of burning (5 per cent nital etch).



This last is important because two scleroscopes may agree upon the standard blocks but will not necessarily agree upon the same roll, so that for accurate results scleroscopes used on rolls should be checked on a standard roll as well as on the standard blocks of the manufacturer. There is apt to be a greater discrepancy between "C" type and "D" type scleroscopes than between scleroscopes of the same type. Since both are used, it is advisable to test rolls with both instruments although the "D" type is more convenient and accurate to read.

Upon completion of the hardness testing, the wobbles, squares, keyways, splines, et cetera, are machined, the journals turned and ground, and the body finish ground.

The grinding of rolls, especially those that exceed 90 scleroscopic hardness, is an operation that has become more and more complicated during the past ten years due to the application of anti-friction bearings, thrust bearings, precision rolling mills requiring extremely close dimensional tolerances and the increasing demands for better and better finishes. Some of the qualities such as hardness, finish, resistance to wear, that make hardened steel rolls useful and necessary in the cold rolling industries are decidedly affected by good or bad grinding. The wheels used should be soft and free cutting, otherwise excessive heating results and is often accompanied by the burning of the roll. There is no formula that may be applied for the selection of the proper wheels et cetera to be adopted that will give the best results in the grinding of hardened steel rolls. A combination of wheels, speeds, cuts, and procedure that is giving good results on a grinder in one shop seldom gives equally satisfactory results on another grinder in another shop or even in the same shop. The grinding wheel manufacturers publish reliable data on the application of their wheels to roll grinding but in the last analyses it will be found that best results are attained by working out the problem in the roll grinding shop in cooperation with the representatives of the grinding wheel manufacturers.

In the grinding of hardened steel rolls there is no short cut to a high finish. It can only be attained by building up the finish with a series of wheels, the expenditure of much time, and a grinder in perfect condition. The number and kind of wheels necessary depends upon the type and quality of finish desired. In some cases one, two, or three wheels may be sufficient but for the highest quality finishes more are usually required. An example of such a series of wheels for the production of a high finish on a new roll by a manufacturer for delivery to a user is as follows:

Wheel No.	Operation	Grit	Abrasive
1	Rough grinding	24	Aluminum Oxide
2	Rough grinding	50	Silicon Carbide
3	Semi-finishing	150	Silicon Carbide
4	Polishing	320	Silicon Carbide
5	Polishing	400	Silicon Carbide
6	Final polishing	500	Silicon Carbide

The first two wheels generally use a vitrified bond while the latter wheels are usually made with an organic bond.

Using such a combination and only regrinding the body after use, the substitution of a 100 grit wheel for wheels 1, 2, and 3 might be considered. The best finish attainable from each wheel is required if a satisfactory final result is to be attained. The too prevalent belief that a poorly ground surface from one wheel can be corrected by the succeeding finer wheel is erroneous, leads to unsatisfactory results on the surface of the product being rolled, early removal of the rolls from the stands, and in some cases actual disaster to the face of the roll. The attempt to remove bad chatter, pronounced traverse marks, slight out-of-roundness, by means of a finer succeeding wheel or a polishing wheel produces an inferior finish on the rolled stock and may ruin the roll.

The presence of chatter on the face of a roll during the early stages of grinding does not usually cause the concern it should. A caution to the operator to keep his wheel clean is often the only comment made. Grinding chatter burns the face of rolls as may be seen from Figures No. 7 and No. 8.

Further finer grinding may or may not remove the chatter. A polishing wheel may apparently have done so but subsequent rolling or etching again beings it out on the surface. The polishing has only masked the chatter.

This is likewise true of bad traverse marks or feed lines. Figure No. 9 represents the surface of a pair of rolls ground with a 320 grit wheel in such a manner that bad traverse marks were produced.

The surface was subsequently finished with a 500 grit wheel which appeared to have removed the traverse lines. Three hours after the roll had been in the mill the traverse lines reappeared. The condition shown in Figure No. 9 is after 48 hours of rolling. In addition, bad traverse marks are often an indication of burning as shown by Figure No. 10.

Whenever bad chatter or bad feed lines are encountered, the roll should be reground with a preceding coarse wheel, grinding off enough stock so that on etching no evidence of feed lines or chatter marks remain.

The grinding burn that occurs when the face of a roll is touched by the revolving grinding wheel while the roll is stationary is particularly destructive and in many cases is not recognized as being serious. It may result from pure accident, such as failure of the work drive while grinding, mechanical failure of the feeding mechanism, or from plain careless grinding. It is a good rule that the work should be revolving and the lubricant be flowing onto the roll before starting to approach the wheel to the roll. If the work is revolving, the lubricant flowing, and the face of the roll is inadvertently touched too hard with the grinding wheel, the roll will be burnt but the resultant burn will not be nearly as serious as if the roll were stationary at the time. Figure No. 11 shows the result of accidentally hitting the face of a roll with a grinding wheel.

Had the roll been revolving at the time, the resultant burn would not have been so serious and the roll might not have been scrapped. Figure No. 12 is the same

FIGURE 11—The resultant burn from accidentally hitting the face of a roll with grinding wheel. (Unetched)

FIGURE 12—The grinding wheel burn of Figure 11 etched with 7 per cent nital.

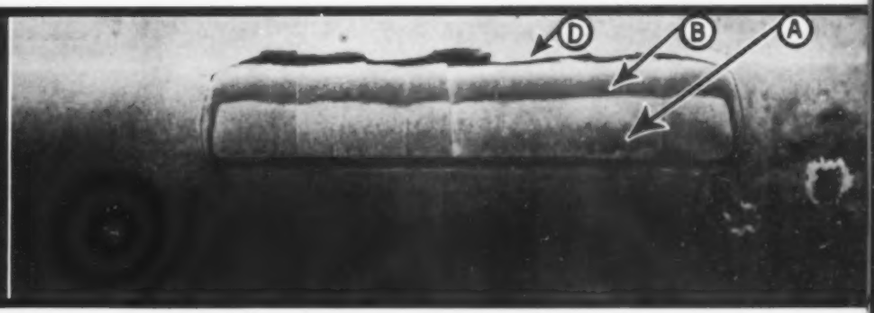


FIGURE 13—Another grinding wheel burn etched with 5 per cent nital, showing crack.

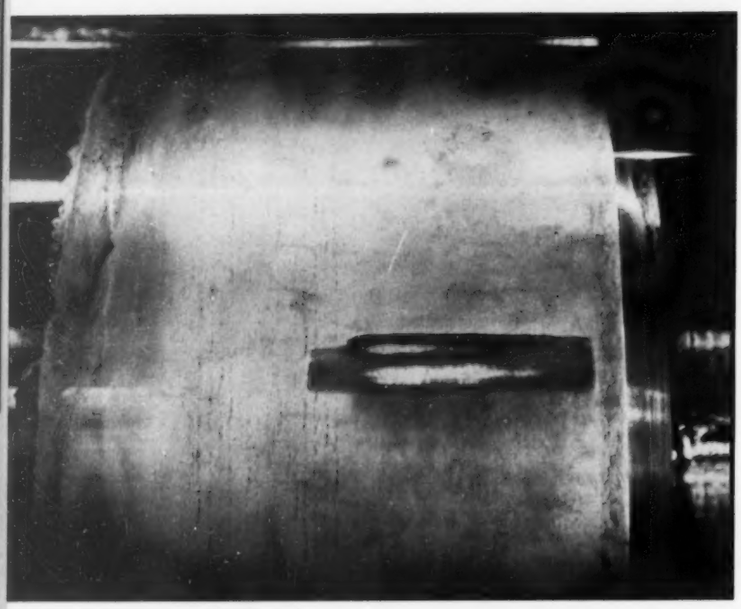


FIGURE 14—A less severe grinding wheel burn with no development of crack. (7 per cent nital etch.)

grinding burn after being etched with 7 per cent nital solution.

Figure No. 13 is another grinding wheel burn. In this case as in the previous one so much heat was generated that the area "A" was raised above the critical point and the subsequent cooling so rapidly that it rehardened.

The area "A" is practically as hard as the portion of the face of the roll not involved. The area "B" on the other hand became hot enough to soften the steel but not hot enough to reharden on subsequent cooling. The area "B" will be found to run between 60 and 80 scleroscope, while the hardness of the remainder of the roll will be unaffected. The softest area is immediately adjacent to that area that rehardened since here the metal reached a temperature just short of the critical. The crack "D" usually accompanies such a severe burn.

FIGURE 15—Grinding burns may produce checks accompanied by onionskin spalling.

It is generally outside the drawn area. The crack is probably due to the fact that as hard steel softens the specific gravity increases and the resultant shrinkage causes the metal to crack. The mechanical action of localized rapid heating and cooling also assists in the cracking.

In some cases where the burn has not been so severe, the crack "D" does not occur. Figure No. 14 is such a burn. Merely grinding such a roll until the visible effects of the burn have been removed is insufficient since the remnants of the "C" shaped crack will appear upon rolling because all the affected metal has not been removed.

If after the visible effects of the burn have been just removed by grinding, the spot is etched with 7 per cent nital solution the characteristic black area of tempered martensite shown at "B" in Figure No. 13 will appear indicating the effect of the burn is still present in the face of the roll. Grinding and etching should be continued until all indication of the effect of the burn has been removed. The roll may then be returned to service with a fair assurance that no further trouble will be encountered from the original burn.

If a hardened steel roll has been ground too heavily or with too hard a wheel, grinding checks may appear accompanied by onionskin spalling. Frequently the edges of the cracks are raised as the surface attempts to contract due to the shrinking of the metal on the surface as it softens. See Figure No. 15.

The effects of accidents that occur in rolling are not generally regarded by operators with the seriousness they deserve. This is true to a large extent because accidents in rolling do not usually result in the immediate failure of the rolls. Very often the worst accidents only result in the removal of the rolls from the roll stands for grinding to remove the visible effects of the accident from the face of the roll. Sometimes the rolls are polished with emery in the stands and rolling continued. Subsequent failure of the rolls some considerable time later is seldom attributed to the prior occurrence that is actually the cause. A study of the history of numerous rolls that have broken, spalled, et cetera, in service leaves no doubt that some apparently unexplainable failures are caused by accidents which have occurred some time prior to the actual failures. Figure No. 16 shows a piece of strip steel and one of a pair of rolls that was in a wreck. The rolls were carefully ground to remove all apparent effects of the injury and returned to service. They were used in a normal manner being in and out of the mill for grinding a number of times without any apparent ill effects from the wreck. Some weeks later a large spall blew out of the face of one roll. The mate was paired with another roll and continued in service when three weeks later it also spalled. In this particular case a record was kept and the rolls carefully observed from the time of the wreck until failure. In most cases, particularly where the accidents are much less severe than the above, due to the considerable time intervening, no one remembers the previous incident that is the real cause of the failure. Subsequent examination of records, microscopic examination, or etching with 7 per cent nital solution may or may not reveal it. This condition presents a most difficult situation for both the user and the manufacturer as it is important that they should have re-

liable information on which to proceed toward the improvement in manufacture and use of hardened steel rolls. The keeping of full and accurate records of the history of the use of rolls by the mills is a great help to both the manufacturer and the user in this respect.

Seven percent nital etching solution is frequently of great help in disclosing what has occurred to a roll that caused its failure. The photograph shown in Figure No. 17 is the face of a roll that spalled in service.

No cause for the failure was apparent until the face of the roll was polished and etched with the 7 per cent nital solution when the appearance of the dark shadowy areas showed that the face of the roll had been tempered in a wreck. A similar situation existed with the roll shown in Figure No. 18.

Etching brought out the dark streak shown, proving it had been subjected to a severe pinch. An 18″ x 42″ four-high mill roll spalled badly near one end. There seemed to be no reason for the failure. The face of the spall was etched, bringing out very fine checks and tempered martensite areas shown in Figure No. 19.

It was apparent that the roll had met with an accident. Investigation by the user brought forth the information that a steel guide had broken loose, passed through the rolls producing the burned streak shown and the mystery was solved. Figure No. 20 is the opposite side of this spall.

The polished streak down the center is the detail fracture starting from one of the checks in the surface. The detail fracture grew inward in a spiral direction increasing in width as it proceeded until the parted area became so large that spalling occurred. The surfaces on either side of the detail fracture represent the fracture that occurred at the time the spall came out of the face of the roll.

It is only infrequently that failure takes place without fragmentation preventing the mechanism of failure from being clearly traced. In the following two such cases fragmentation has not destroyed the evidence by which the failure may be traced from its start to completion. Figure No. 21 shows the surface of a spall from a work roll that failed due to a detail fracture originating in the surface at point marked "A".

Figure No. 22 is the spall of Figure No. 21 after etching with 7 per cent nital.

Figure No. 23 shows the detail fracture on the reverse side of the spall.

Figure No. 24 is a sectional view of the spall and shows how the detail fracture grew inwardly from the surface in a spiral direction. The detail fracture starts from the point "A" in the surface which is the point "A" of Figures No. 21 and No. 22.

Further the direction of travel is opposite the direction of rotation of the roll.

Figure No. 25 is a view of a 12″ x 29″ work roll from a four-high reversing mill. Since this roll was used in a reversing mill, two detail fractures starting from an injury in the face of the roll proceed inward in opposite directions, widening out as they grow.

The boundaries of the forward growth of the fractures are indicated by the rings in the polished surfaces of the detail fractures.

In the case of rolls that run in one direction during one campaign in the mill and then on their return to the mill travel in the reverse direction, the fracture

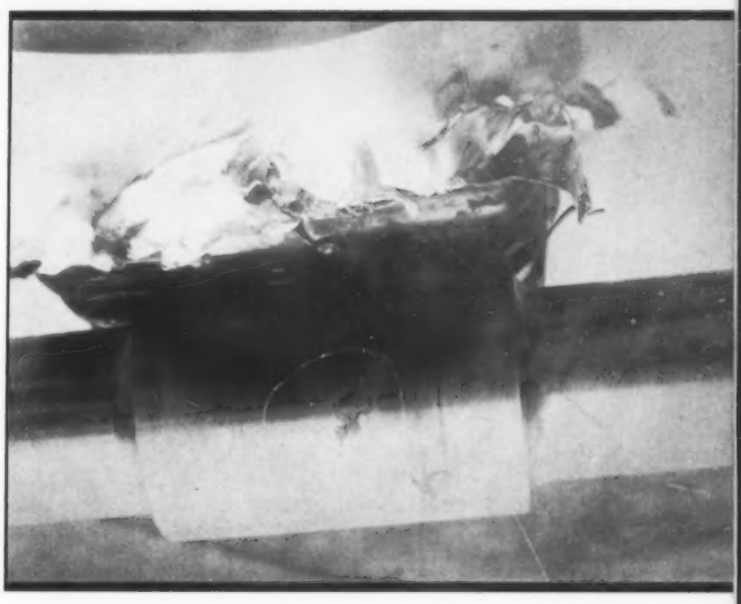


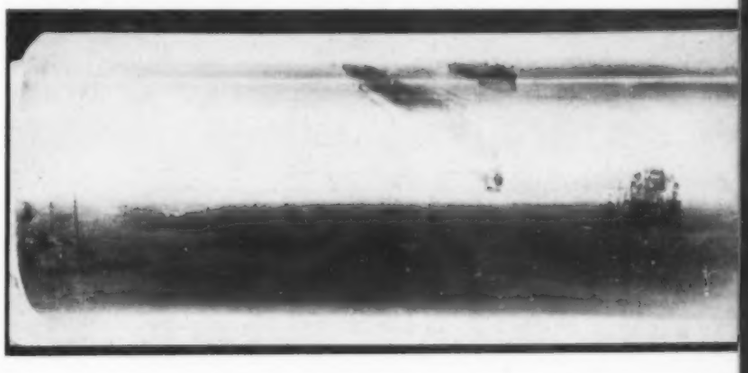
FIGURE 16—Piece of strip steel and one of a pair of rolls that were in a wreck.

disclosed at failure is complicated and can not be so readily interpreted. In some instances we have found a series of detail fractures starting from the end of each previous one, each growing in an opposite direction and under the preceding one as shown diagrammatically in Figure No. 26.

Metal defects on the edges of strip or sheets are potent causes of wrecks especially in tandem rolling at high speeds where considerable tension is carried between the stands. Figure No. 27 shows a defect in the edge of the strip.

These defects cause the steel to tear on the edge just before entering the rolls. Frequently a corner will turn over doubling the thickness passing through the mill. This will momentarily concentrate approximately the load of one screw on a very small area of the face of the roll. Since the stresses in the faces of rolls under normal loading are of a very high order,

FIGURE 17—Effect of a wreck on the face of a roll. (7 per cent nital etch.)



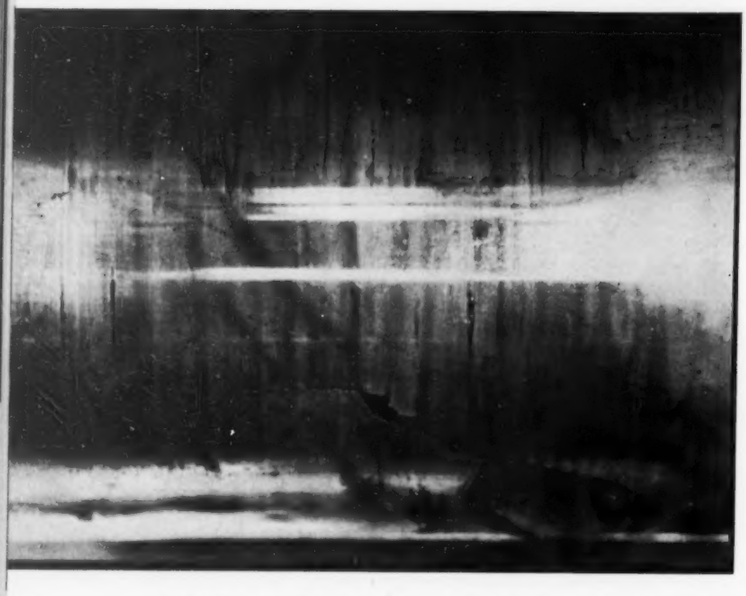


FIGURE 18—Effect of a pinch on the face of a roll. (7 per cent nital etch.)

such an occurrence produces a tremendous stress at this point causing bruising, checking, and burning. Failures along the edges of rolling tracks can often be traced to such occurrences. Mills using clean edge strip have the best operations and roll life.

Another source of failure along the edges of rolling tracks can be traced to too much deflection in the mill producing excessive pressure on the edge of the metal being rolled.

Rolls are crowned to offset the effect of deflection but practical rolling considerations limit the amount of crown that can be used. (One of the contributing reasons for backed up mills.) Sometimes deflection from shear stresses is neglected with subsequent serious consequences.

The heavy reduction of thick metal may cause the burning of the faces of rolls. This is most prevalent in the rolling of non-ferrous metals but it sometimes happens while rolling steel.

The checking shown at "A" and "B" in Figure No. 28 was caused by a large difference in velocity between the roll face and strip due to heavy reductions.

At "A" in Figure No. 29 tempering and checking due to slippage between the face of a roll and the stock can be seen.

The effects of the local heating of the face of the roll shown at "A" in Figure No. 29 has softened and checked the metal in the dark path brought out by the 7 per cent nital etch. In addition the whole face of the roll has been softened by heating. This is strikingly demonstrated by the Rockwell hardness readings taken on the face and back of the spall shown in Figure No. 30.

Path "X" is the black path "A" in Figure No. 29.

Path "Y" is the hardness of the face of the spall about 1″ away from "X" and is higher. Path "M" represents the hardness of the fractured face of the spall directly under path "X" while path "N" is directly under path "Y". The hardness readings of path "M" and "N" approximately 3/16″ under the surface of the roll show conclusively that the surface of the roll has been tempered in service. If this were not the case the hardness of the back of the spall would be less than or equal to the hardness of the surface, not higher than the surface.

Additional evidence of the softening of the metal shown in the dark streak of Figure No. 29 lies in the relative specific gravity of the metal in this streak and the unaffected metal from the back of the spall. The specific gravity of soft steel is greater than that of hard steel. Consequently the specific gravity of the back of the spall should be greater than metal from the face of the spall. Actual determination of the specific gravity of the metal from the back of a similar spall was 7.5631 while the specific gravity from a similar dark streak on the face of the spall was 7.6189.

The roll from which the spall shown in Figures No. 29 and No. 30 came failed because the thermal gradient between the surface and the adjacent layers was so steep the resultant stress combined with the mechanical stress of rolling caused a lesion in the metal considerably under the surface. Once this happens a detail fracture starts and failure results. Spalls of this character are usually deep and of large extent.

Failures from rapid heating of the face of rolls may be to some extent avoided by careful preheating of the rolls before starting rolling operations. This will minimize the temperature gradient between the outside and inside because although the rolling operation will generate just as much heat, the temperature differential will be less due to greater loss from radiation and conduction, etc., as the temperature increases.

Preheating hardened steel rolls before starting rolling

FIGURE 19—Etching with 7 per cent nital may bring out injuries to roll faces otherwise invisible.

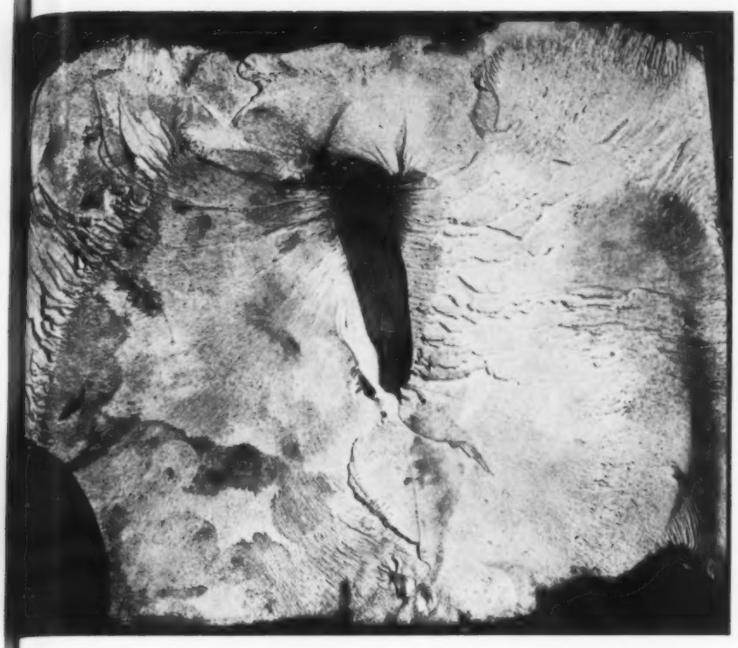


FIGURE 20—View of opposite side of the spall shown in Figure 19.

operations is a good thing to do under almost any circumstance. Hardened steel is brittle at low temperatures. Its ductility increases rapidly with temperature within the ordinary range of cold rolling operations, unaccompanied by a proportionate decrease in strength and hardness. The most desirable method of preheating is to supply the heat slowly through the bores of the rolls since this insures the center being heated and the best distribution of stress during the heating up operation. Since all hardened steel rolls, except the smaller ones, have an axial hole through them, this can usually be readily done. Numerous failures of other kinds of rolls as well as hardened steel rolls have occurred from starting to roll on them when at a low temperature. With a bore present in hardened steel rolls it is very easy to make convenient and inexpensive arrangements for preheating. In addition to preventing failures from rolling at low temperatures, operators find they have less trouble in bringing the rolls to shape on starting up.

Most cold rolls are cooled externally with water or soluble oil solution. Generally no attention is paid to the temperature of the coolant. Very low temperature coolant is undesirable and has been known to cause the breakage of cast as well as forged steel rolls. Some of the mills are using soluble oil solutions that are heated and maintained at a constant temperature. With a closed system this is not difficult or expensive to do and is highly desirable insofar as the rolls are concerned. Those mills adopting this practice have much less roll trouble.

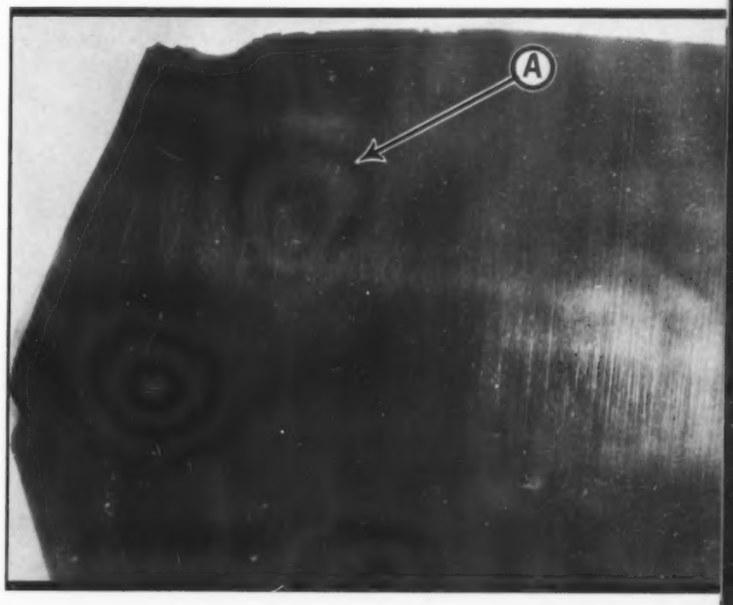
At one time it was almost a universal practice to cool the centers of hardened steel rolls with cold water, under the belief that without this cooling a proper shape for rolling could not be maintained. This belief is undoubtedly true in some instances but it has been disproved in a number of others and the practice is not now nearly as universal as it was. The cooling of the centers of rolls with water is still done in a number of mills but it is of doubtful benefit in most cases insofar as rolling is concerned and definitely bad for the rolls. It is particularly harmful to small and medium sized rolls. This may be indicated by comparing 20″ diameter and 10″ diameter hardened steel rolls. The temperature gradient in the former is nearly one-half that of the latter for the same face and bore temperatures, which is approximately true in many such cases, while the ratio of the cross sectional areas available for the absorption of the stress produced by the thermal gradients is four to one. Therefore, the harmful effect of increasing the thermal stress in the cross sections of the rolls by water cooling in the bore is far greater in the smaller diameter rolls.

There have been a number of small mills where numerous failures have been stopped by the elimination of water cooling in the bore. Some large mills have also found it advantageous to abandon the practice. In fact some of them are heating the coolant entering the bore to maintain a more even temperature in the cross section of the rolls and have obtained the benefit of the increased ductility in the rolls by operating at slightly elevated temperatures.

Steep temperature gradients sometimes produce high tangential stress in the bores of rolls. This is more prevalent in the lower ranges of diameters. The radial cracks running out from the bore on the end of the journal in Figure No. 31 are the result of this effect.

The cracks have progressed from the center of the end of the journal. They did not proceed into the journal on the opposite end where the cooling was not as effective. This is one of several 10″ diameter rolls

FIGURE 21—Surface of a spall from work roll that failed due to detail fracture at "A". (Unetched.)



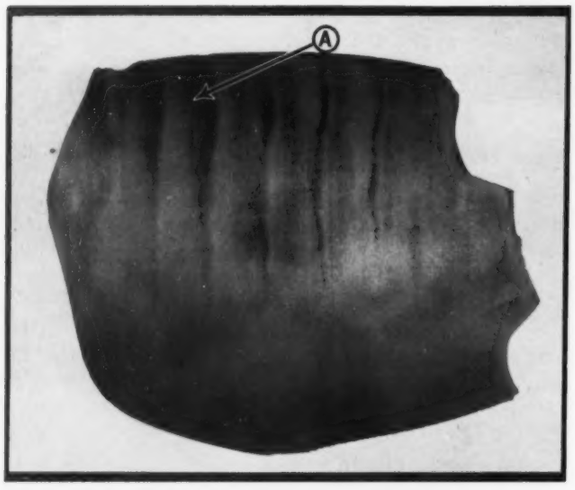
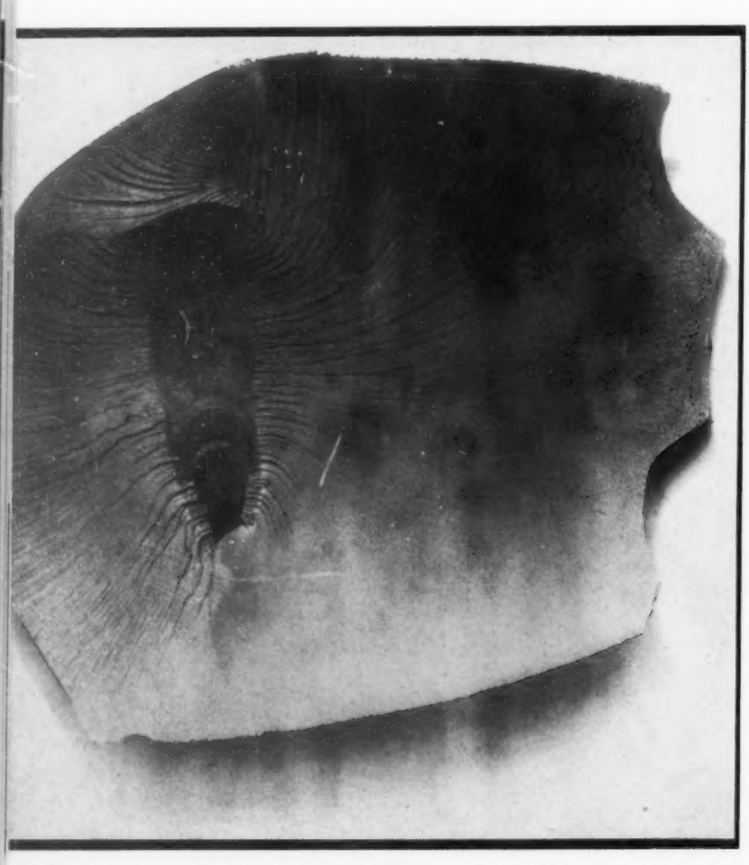


FIGURE 22—The spall of Figure 21 after etching with 7 per cent nital.

that failed in a similar manner. The user of these rolls found with minor alterations in his rolling practice he could produce satisfactory metal without water cooling in the bores and eliminated it entirely. This was about three years ago. There have been no failures since.

FIGURE 23—Opposite side of spall shown in Figures 21 and 22.



Another serious cause for roll failure from faulty operation is that of overheated journals. It is true that the development of various types of anti-friction bearings is to a large extent eliminating this trouble. However, failures still occur on two-high mills which continue to use the conventional bronze or babbitt bearings with which a continuity of lubrication is a decided uncertainty.

Failures from this cause most frequently result in more or less severe spalling on the ends of the bodies adjacent to the necks. This is due, of course, to the heat having been transmitted too fast from the neck to the roll body. It also causes the ends of the body to increase in diameter. This increase in size results in exceedingly high pressure on the ends of the roll bodies with the result that spalling often occurs. An example of this can be seen in Figure No. 32.

Overheating causes checking of journals with possible eventual failure. These appear at first as fine hair cracks running in an axial direction. The cracks at first are usually quite numerous but short in length.

As overheating continues they grow. They may join together in the same plane until a continuous crack runs across the entire journal. If this process keeps up indefinitely the roll may finally fail by having the cracks extend all the way through to the bore. Figure No. 33 shows a roll which failed in this manner. In addition to the journal failing, the body cracked longitudinally as well.

Figure No. 34 shows a two-high-mill roll which failed from overheated journals. The portion of the journal adjacent to the cracked end of the body showed blue temper colors from the heat.

One end of the body cracked due to an increase in size causing excessive pressure on this end. Figure No. 35 is a close-up view of one neck of this roll.

Bad score marks on the journal of a roll, especially on or near the fillet may be a cause for failure. The resultant grooves act as points of stress concentration and often are the nuclei for detail fractures that eventually cause the necks to break off.

Polishing of rolls in the stands is sometimes necessary. Fixed abrasives such as emery cloth seem to give the best finishes. Loose abrasives such as emery powder are more apt to tail depressions in the surface. Stick grinding should never be done in lieu of machine grinding. Grinding with a stick and abrasive, if not done properly, may cause spalling or checking of the surface from the rapid generation of heat. More polishing of rolls in the stand is done in non-ferrous rolling to keep the rolls clean than is done in the rolling of steel.

When hardened steel rolls are taken from the stands for grinding, enough should be removed from the surface to insure that all effects of the previous rolling have been completely removed. To do this, it is usually necessary to grind off more metal than is required to just remove the last visible traces of the previous rolling. Whenever bruises, checks, scuffing, etc., are present the spots should be located and after grinding, polished and etched to see that all effects from them have been removed.

After grinding, rolls should be checked for concentricity, out-of-roundness, taper, and crown. In checking the crown, it is not enough to determine the diam-

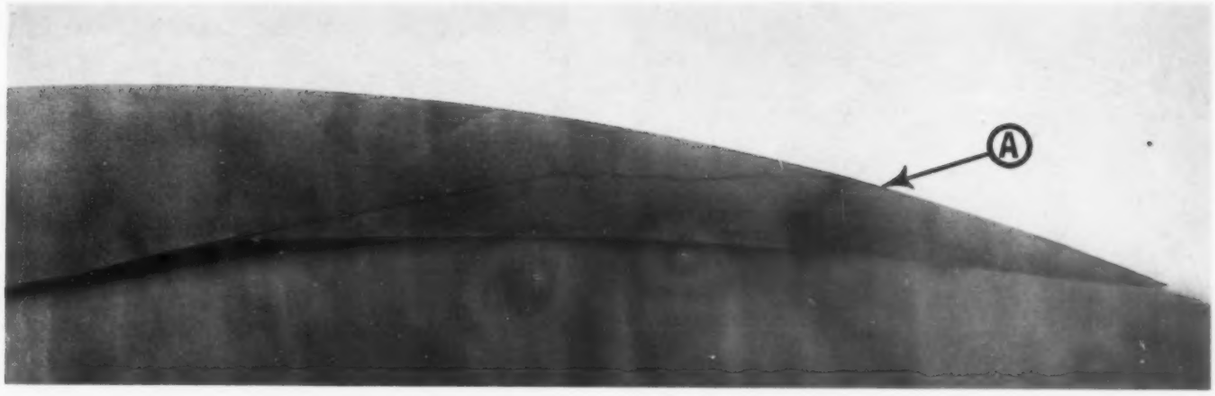


FIGURE 24—Sectional view of spall of Figures 21, 22 and 23, showing detail fracture.

eters at each end of the bodies and the middle. They may be correct but the contour between the middle and the ends may vary considerably from that desired. The diameters at regular intervals between the middle and ends should be determined and compared with the desired crown contour. This is conveniently done by means of a saddle gage shown in Figure No. 36.

Neglecting to check rolls for crown, straightness, etc., after grinding, accounts many times for peculiar and annoying behaviour in the mills and may in some instances be the cause of failure.

Whether hardened steel rolls should be ground on centers or resting on journals depends upon circumstances. Grinding on journals is the usual practice in rolling mills and for the heavier rolls and rolls with a large ratio of length to body diameter is without question the best and quickest method. With the smaller rolls it probably does not make much difference whether they are ground supported on centers or on journals. Owing to the multiplicity of grinding operations, roll manufacturers prefer grinding on centers while users prefer re-grinding with their rolls supported on journals.

Hardened steel rolls should be stored in clean, dry, and warm surroundings. Care should be taken that they are not subjected to sudden changes of temperature. They should be protected with a good rust-preventing grease and when they are supported on wooden blocks the wood should be covered with a piece of strip zinc otherwise pitting by attack from compounds in the wood may result.

Forged steel rolls either fully hardened or heat treated are used for a wide variety of purposes. The fully hardened rolls are used mostly for the cold rolling of flat metal. More are used for the rolling of steel than any other metal, but their use is well established for the cold rolling of brass, copper, aluminum, zinc, tin, lead, platinum, gold, silver, and magnesium. The hardness of this type of roll usually exceeds 90 scleroscope. Those that are used to produce very fine finishes or roll very thin metal may have to be 100 scleroscope or harder. Rolls of this type are usually made from the following type steel analysis:

C	Mn	Si	Cr	One or more of the following usually added
.85	.35	.25	2.00	V—Mo—Ni—W—Co

They were first used in two-high, single-stand mills and many are still used for this purpose. Their hardness and finish will depend upon the operations being performed. Figure No. 37 shows several hardened steel work rolls. The first roll on the left has a typical four leaf clover wobbler handed down from the old cast rolls they supplanted. This wobbler was later improved by altering to the shape shown in the second roll from the left. The most modern type of drive ends are shown by the last three on the right.

Hardened steel rolls are used in three-high mills. The three-high mills, however, with the exception of some mills for rolling aluminum are generally small in size if used for cold rolling.

The advent of the backed-up mills, the application of anti-friction bearings with the attendant increase in speeds, brought about a great expansion in the cold rolling industry. These new mills have called for radical departures in design of forged steel rolls, and an entirely

FIGURE 25—View of detail fractures in both directions on reversing mill roll.

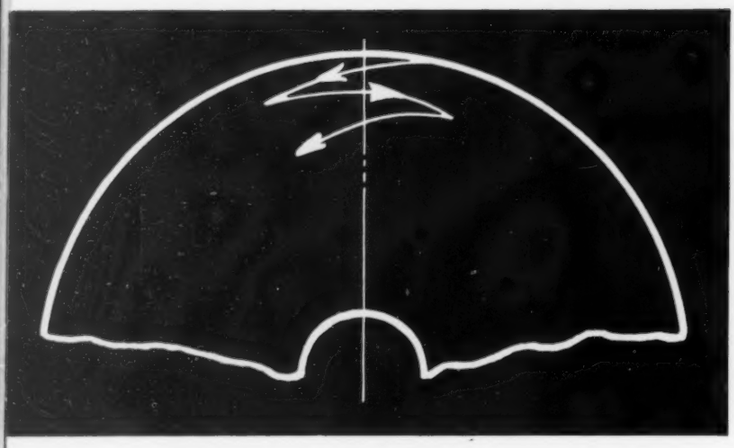


FIGURE 26—Diagram showing series of detail fractures growing in opposite directions from reversal of direction of rotation.

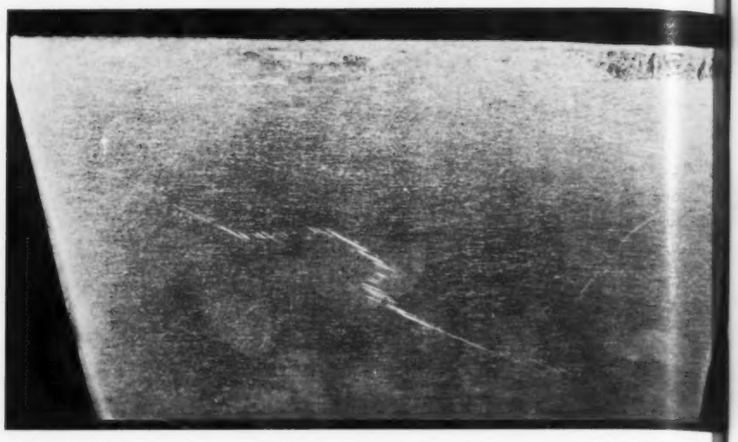


FIGURE 27—Defects in the edge of strip which may cause a wreck, especially in high speed tandem rolling.

new type of roll; namely, the back-up roll. Fifteen years ago approximately 400 feet/minute was considered a high speed. Now cold mills are running at 1500 feet/minute and 2000 feet/minute is being talked of. Hot rolled steel strip is being rolled from approximately .100″ to .009″ in four or five stand tandem four-high mills at finishing speeds of 1500 feet/minute without any intermediate anneal—an unheard of procedure until the backed-up mill appeared. So radical a departure from the old staid and established practice brought forth many mechanical problems but they have also brought forth many metallurgical and manufacturing problems for the forged steel roll maker.

The forged steel roll maker has had to meet an entirely new set of conditions and adopt new manufacturing methods to meet the various conditions that have arisen as each new type backed-up mill has been built. The single stand four-high mill has expanded to the four and five stand tandem mills. The single stand reversing mill, the mills utilizing high tension in connection with the drive and the so-called Steckel mill which rolls by drawing the metal between rolls that might be called rotating dies, all present different conditions. The work rolls in the single stand reversing mill have to be roughing rolls, intermediate rolls, and finishing rolls all at the same time. These mills may be

FIGURE 28—The checking at "A" and "B" was caused by great difference in velocity between roll face and strip due to heavy reductions.

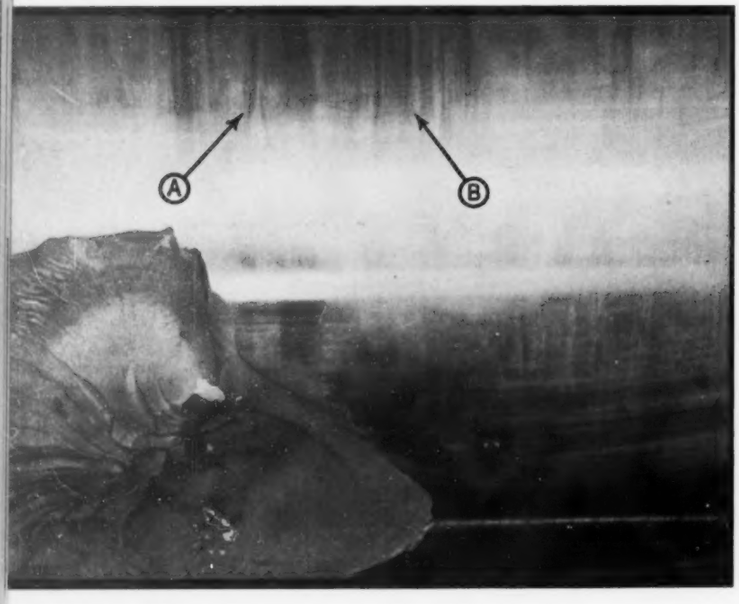
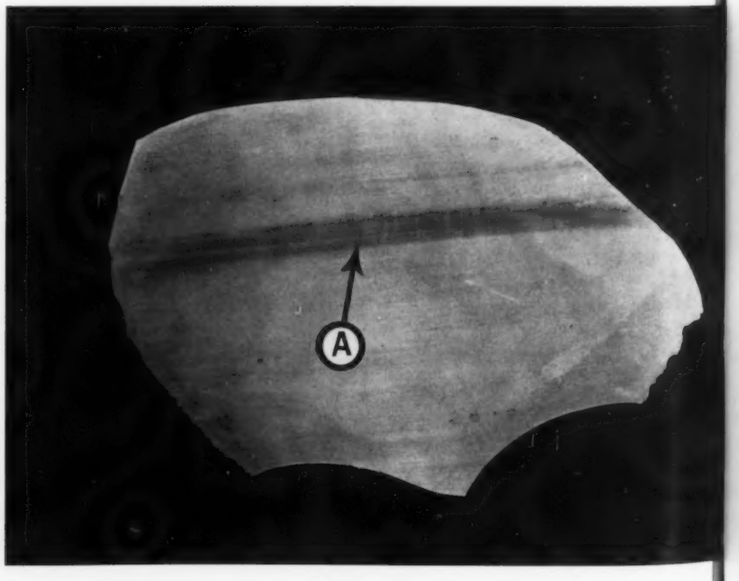


FIGURE 29—Friction burn on face of spall due to slippage before roll face and stock.



running on strip steel either carbon or alloy or they may be used for tin plate. The three stand tandem mills running on auto body sheet, the four and five stand tandem tin plate mills, and the two-high and four-high skin pass mills, all presented still different conditions for which the hardened steel roll maker had to work out an answer in a very short time with the scantiest data available.

The skin pass mills and the smaller two-high mills usually require rolls of the maximum hardness while the tandem mills and the high speed mills seem to get best results from rolls drawn back to hardnesses somewhat less than the maximum. In this connection it is well to bear in mind that it is always the best practice to use at the minimum hardness that will give satisfactory results.

Cold rolling has been practiced in the mints for a great many years, in fact the earliest hardened steel rolls were made for the mints in Europe. The mills in the mints using forged hardened steel rolls are usually of small to medium size for finish work. Occasionally they use forged steel rolls for the breaking down operations to obtain rolls of greater strength and ductility.

There are a number of very small rolling mills using small work rolls for special purposes such as wire flattening, reduction of heddle wire, spring wire, razor blades, vacuum tube filaments, etc. The jewelry findings trade have a number of small mills and in some instances use specially shaped work rolls. In some cases the bodies of the rolls are eccentric with the necks for the rolling of tapered blanks used in the production of spoons and forks. These are usually designated grading rolls. Most of these rolls are small and are generally required to be very hard. They are seldom used with a Rockwell hardness of less than 65 "C". In many instances these rolls have to be produced with an extremely high finish for the rolling of gold plated stock, etc.

The back-up rolls in the four-high and cluster mills perform primarily a supporting function. However, it is a mistake to assume that being supporting members they do not deserve consideration as rolls. When the first backed-up mills were built, cast back-up rolls were used and many cast rolls are still being used for this purpose. But when it became apparent that harder, stronger, and stiffer back-up rolls would be required to meet the most severe conditions, forged steel rolls were tried. They, at first, were only for the smaller mills, but the use of forged steel back-up rolls has increased steadily so that today rolls weighing as much as 73,000 pounds are being made. Several such rolls have given complete satisfaction for three years and their ultimate life is not yet in sight. Back-up rolls less than 36″ in diameter are usually made in one piece whereas the larger rolls are made either as single forgings or as an assembly of a sleeve shrunk on a mandrel. We have had built-up backing-up rolls composed of forged steel mandrels and forged and hardened steel sleeves in service since about 1926. The first small single piece roll was placed in service in 1926.

Forged steel mandrels are not essential for built-up back-up rolls, cast steel mandrels being also used. The forged steel mandrel is, however, more reliable, stronger, and stiffer. In addition the forged steel mandrel can be made hard enough on the journals to withstand to a reasonable extent the wear from the inner races of roller bearings. So far, of all the built-up backing-up rolls we have made, only one forged steel mandrel has failed in service and that came from the mandrel being fire cracked in forging.

Many of the users of backed-up mills have sent their worn out cast steel back-up rolls to the forged steel roll makers to be turned down and used as mandrels on which hardened forged steel sleeves have been shrunk giving a superior back-up roll. This is a worthwhile and economical procedure. A typical performance of a group of such rolls in service is given in the table below.

The application of sleeves to mandrels to form back-up rolls requires skillful engineering. Lack of proper consideration of all factors has led to slippage, splitting longitudinally, and other failures. The walls of the sleeves must not be too thin or else they will roll out between the mandrel and the work rolls and become loose. If the walls are made heavier than required they are unnecessarily expensive. Temperatures of operation have to be considered in conjunction with coefficient of conductivity and expansion and past experience to determine the proper shrinkage of the sleeves on the mandrels.

Up to approximately 36″ diameter either built-up

SERVICE FROM BACK-UP ROLLS MADE BY PUTTING HARDENED STEEL SLEEVES ON WORN OUT CAST STEEL ROLLS

Shipped	Kind of Mill	Diameter Put Into Service	Diameter at Present Tonnage	Reduction in Diameter	Tons Rolled	Hardness D Type Sclero-scope	Present Condition
May 1935	Hot	46-3/8″	45-1/2″	7/8	810,000	74/77	In service
May 1935	Hot	46-1/2	45-9/16	15/16	735,000	64/67	In service
Jan. 1936	Hot	46-9/16	46-1/8	7/16	518,000	65/68	In service
Oct. 1936	Hot	46-1/2	46-7/32	9/32	345,000	63/67	In service
Nov. 1936	Hot	46-11/16	46-1/4	7/16	325,000	63/64	In service

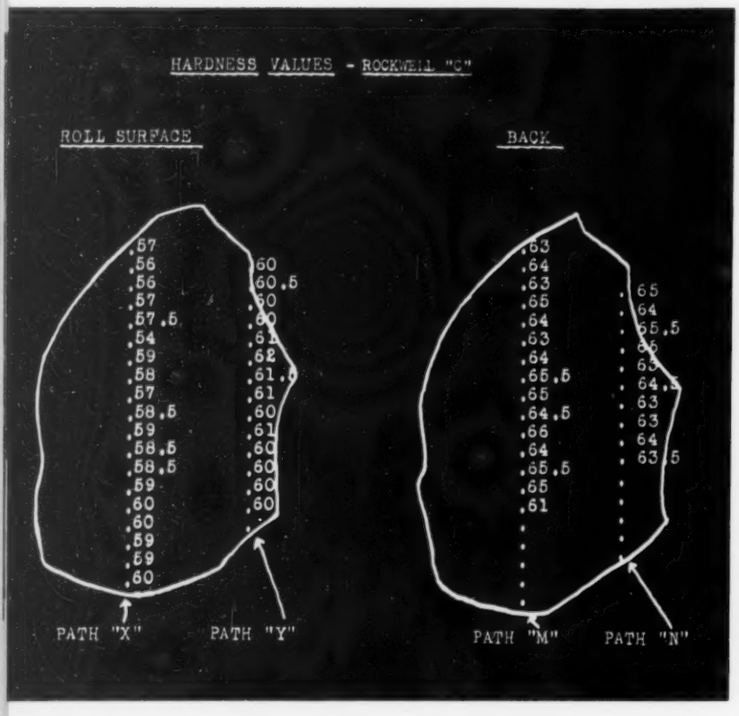


FIGURE 30—Rockwell hardness readings on the spall of Figure 29.

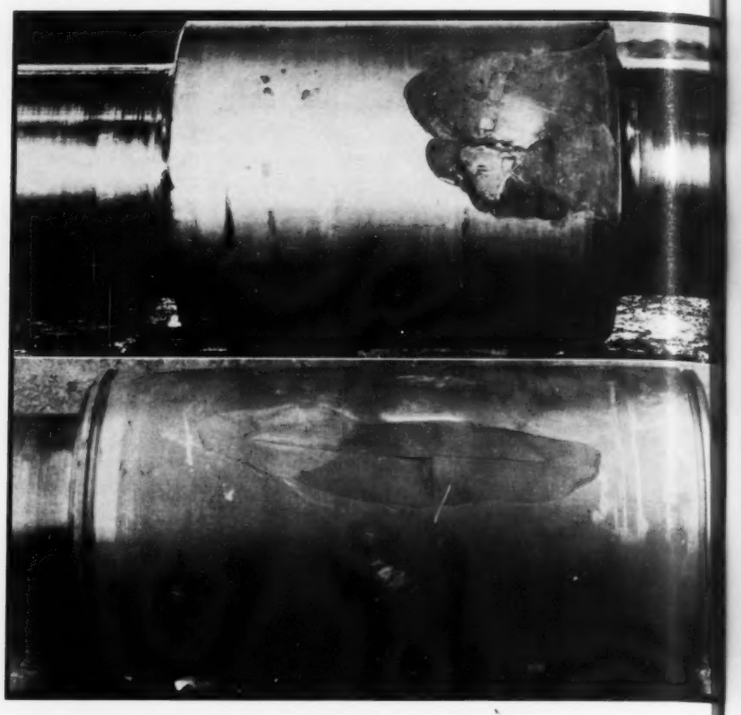
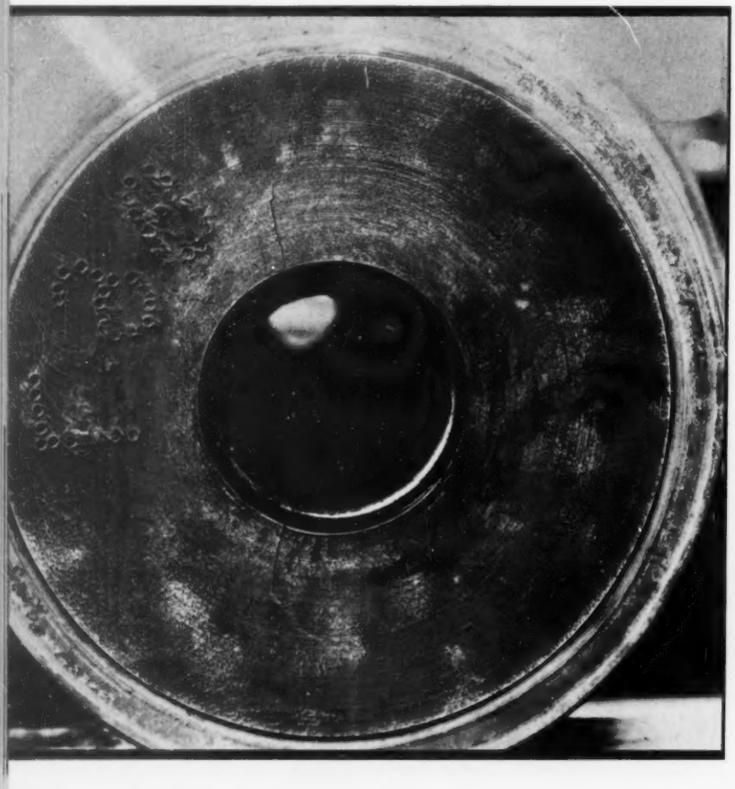


FIGURE 32—(Above)—Spall from pressure caused by expansion of end of roll from overheated journal.

FIGURE 33—(Below)—Failure of roll from overheated neck.

FIGURE 31—Radial cracks in bore may result from steep thermal gradients.



or one piece back-up rolls are almost always 80-90 scleroscopic hardness. Above approximately 36″ in diameter, forged steel back-up rolls for cold rolling run from 65 to 80 scleroscopic hardness, depending upon size of work roll and service. For hot rolling, the scleroscopic hardness is usually less than 70. The effective depth of hardness is approximately 2″ to 2½″.

Forged steel rolls are not confined to the cold rolling of flat metal. They are used for many other purposes in the rolling mills such as levelling machines, hot and cold coilers, pinch rolls, straightening rolls, edging rolls, cold rolling bars and others.

The rolls used in cold levelling machines are not subjected to heavy pressures and so do not need to be of maximum hardness. They do however have to withstand wear and maintain a bright finish for considerable periods of time so are usually made with a scleroscopic hardness greater than 90. The ratio of length to diameter for leveller rolls is large and when thick and narrow material is being levelled, bending stress of some magnitude may be encountered in the middle, especially if a pile up occurs while a piece is passing through, resulting in the permanent bending of the rolls. For this reason we prefer to make leveller rolls from a high carbon alloy steel with a high elastic limit rather than use a low carbon steel and carburize it, although we make both kinds of leveller rolls. Further, where service is severe and rolls have to be ground often the greater depth of hardness of the high carbon alloy steel gives a longer life. Cold uncoilers and coilers use somewhat

similar rolls at the same hardness as above. Sometimes the uncoiler is run in conjunction with a leveller to straighten out the material before it enters the mill or continuous pickling machines. Under the above conditions severe shock loads may be encountered in which case we may supply a carburized roll. Forged steel rolls are also used in machines for the levelling of hot sheets and plates. This type of roll is softer than the type used for cold levelling, usually about 70 scleroscope.

There are a great many forged rolls giving excellent service in various mills as hot pinch, hot coiling, and hot reeling rolls. This type of roll is ordinarily made 80-90 scleroscope. At this hardness they give very good wear, do not gather or break, and give a long life in service.

Bridle and tension rolls are regularly made with a scleroscopic hardness of 95 to prevent scratching and pick up that would injure the stock passing over them.

Hardened forged steel rolls are not extensively used in the cold rolling of bars or shapes. However, when the stress is higher than cast rolls will permit or very

FIGURE 36—The use of a saddle gage is desirable to determine actual roll contour.

FIGURE 34—A two-high mill roll which failed from overheated journals.

FIGURE 35—A close-up view of one neck of the roll in Figure 34.

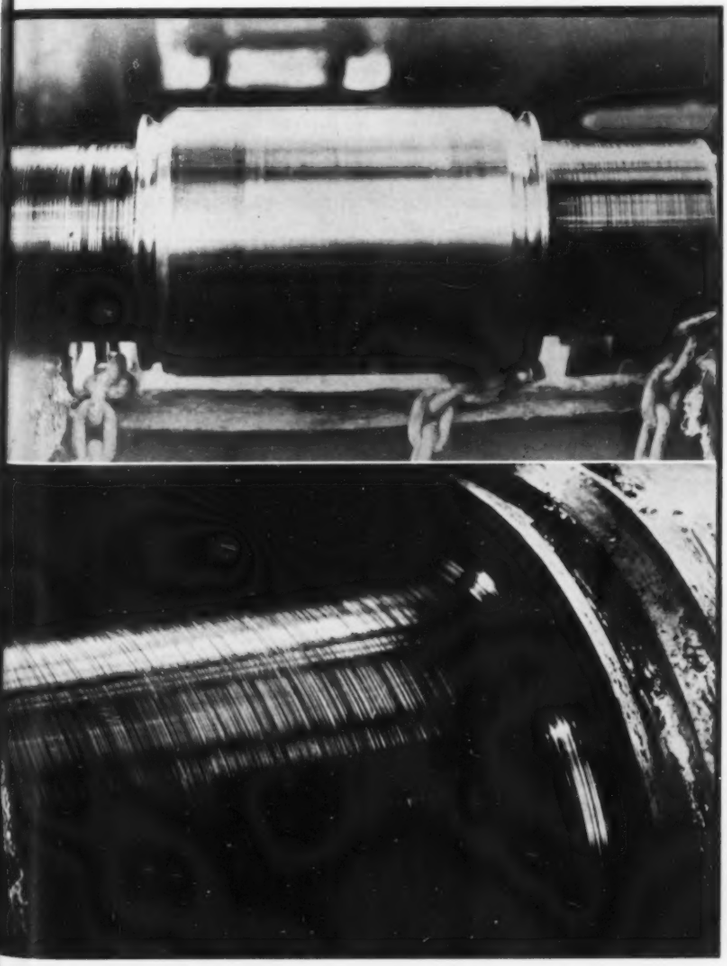


FIGURE 37—Steel work rolls of various types, with hardness and finish according to the operation to be performed.

FIGURE 38—Hardened steel roll for cold rolling square stainless steel bars.

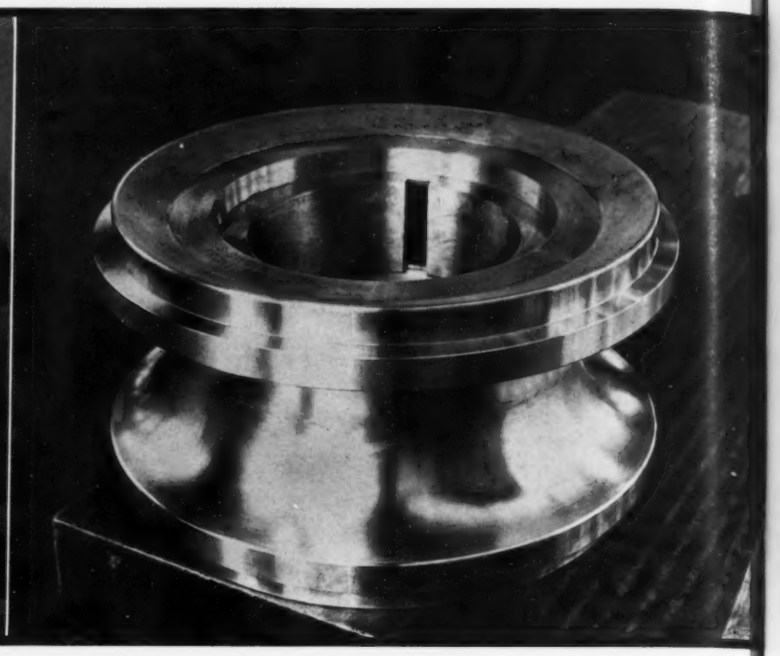


FIGURE 40—Hardened steel straightening roll for bar or tube straightening.

high finish is desirable, or other special conditions exist, they do find application.

Figure No. 38 shows a hardened steel roll used for the cold rolling of square stainless steel bars.

This roll was 95 scleroscopic hardness.

Figure No. 39 shows a heat treated roll for cold rolling round bars of a copper alloy. The hardness of this roll was 75 scleroscope.

Some other forged steel rolls of special shapes are those used in the various types of bar and tube straightening machines. Rolls of this character are made over a wide range of hardness from the maximum of 100 scleroscope to approximately 45 scleroscope. The hardness depends upon the service they are intended for.

When hot rolled bars only are to be straightened deterioration of the surface is not important so that the lower ranges of hardness are used, but in the case of heat treated or hardened or cold drawn bars, the high hardnesses are used. Some of the straightening machines requiring hardened steel rolls are employed in the straightening of ferrous and non-ferrous pipes and tubes. Where it is necessary to straighten cold drawn bars and tubes, the finish on the rolls is usually high, in some cases a mirror finish being required, since in addition to straightening, the machines are used for planishing operations. For such service hardened forged steel rolls have a distinct advantage, being stronger, having a finer grain, and being susceptible of

FIGURE 39—Drawing of heat treated steel roll for cold rolling round copper alloy bars.

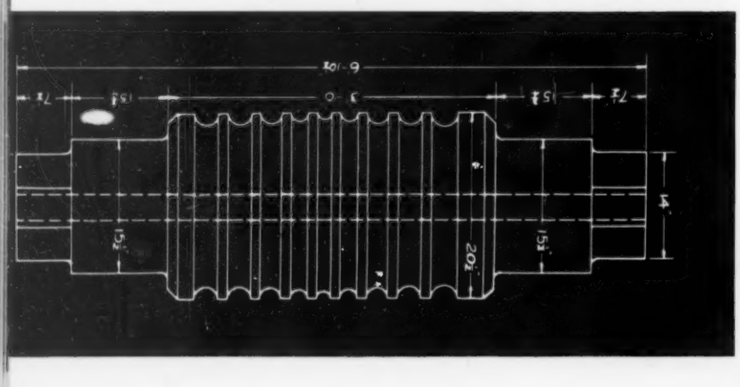
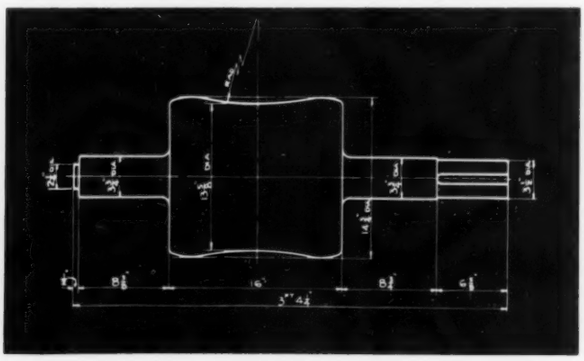


FIGURE 41—Drawing of bar straightening roll.



very high finishes for transmission to the product being worked upon. Figures No. 40 and No. 41 show two hardened steel straightening rolls used for bar or tube straightening. In addition to these standard types there are numerous hardened steel rolls of special shapes for the straightening of extruded angles, architectural shapes, etc., that have to maintain a high finish on the straightened material.

Several years ago some of the steel mills attempted to cold roll unpickled hot rolled strip on standard hardened steel work rolls. The results were disastrous from failure of the rolls by spalling on the faces. To meet this situation, the forged steel roll maker has developed a roll of special composition and manufacture for this purpose. The mills are now able to cold roll unpickled hot rolled strip with very satisfactory results.

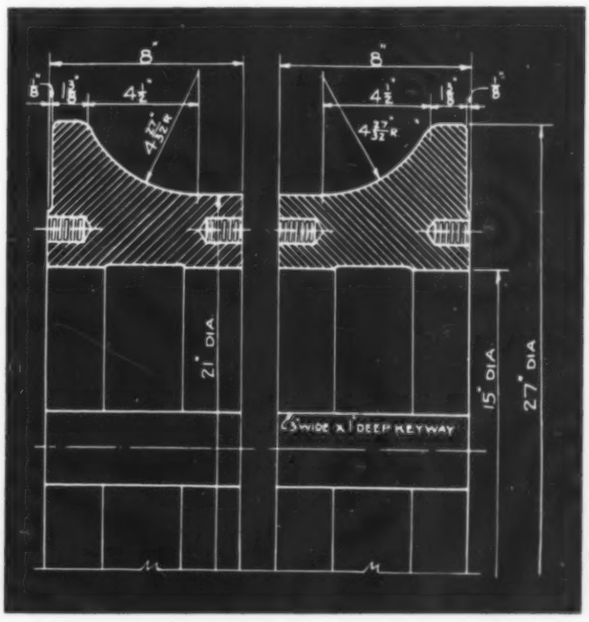
With the development of pipe made in automatic forming and electric welding machines an entirely new type of roll was required of the forged steel roll maker to form the pipe from strip or skelp. Forged steel rolls for this purpose have been in service for about ten years. The maximum hardness is usually in the 80/90 range while for some purposes they can be successfully used down to as low as 60 scleroscope. These rolls maintain their shape, do not become readily dented from the ends of the strip, and wear extremely well. Their depth of hardness is such that their ultimate life is very long. Figure No. 42 shows such a roll.

Mention has been made earlier of the burning of the face of hardened steel rolls due to large differences in velocity between the face of the roll and the metal being rolled when heavy reductions are taken on thick metal and that this was particularly true in the non-ferrous cold rolling industry. To meet this situation the forged steel roll maker has developed a special roll for this purpose. The analysis and method of manufacture is different from that used in standard work rolls. These rolls are usually shipped to the user with relatively rough ground finishes on the body. In fact, a great many are shipped with a sandblasted or grit blasted surface, it having been found that surface checking from burning due to friction was materially retarded by the use of such a surface. This is probably due to the retarding of slippage between the face of the roll and the material being rolled and the increase of the ratio of the surface to adjacent volume decreasing the stress produced upon heating from friction. Rolls of this character are usually designated as running down rolls and their scleroscopic hardness runs between 70 and 90, depending upon the metals being rolled and the conditions of operation. These rolls are characterized by great strength, freedom from spallage, and the ability to withstand severe and unexpected usage. They are considerably less expensive than the harder work rolls. These rolls are used on metal that has ordinarily been through the breakdown operation and in some instances overhauled or annealed. For the breakdown operation in the non-ferrous industries, forged steel rolls are used with scleroscopic hardness usually running under 70. Their main requirement is that they shall not break or spall. Maintenance of a smooth finish is not ordinarily of much consequence. We have known forged steel rolls in this service to stay in the stands several years without having to be polished in the stands or removed for grinding. In fact too smooth a surface is ordinarily detrimental to rolling operations, since a smooth surface makes it difficult to enter the cast ingots for a heavy reduction. During the past several years the forged steel roll maker has been gradually applying forged steel rolls to the hot rolling of non-ferrous metals. Starting with a single installation, the development has grown slowly until there are now several successful installations in service. Some of these are outstanding in their performance. One that may be mentioned is a 24″ x 72″, two-high hot reversing mill in which a pair of forged steel rolls has produced over 26,000,000 pounds of copper, the rolls being removed from the stands only four times for machine grinding. These rolls are still in service. It is probable that the application of forged steel rolls to hot rolling in the non-ferrous industries will continue to grow. They are being used for various operations in addition to that of hot breaking down. One of their great advantages is that they do not seem to deposit metal in the product being rolled, although they do eventually fire crack sufficiently to have to be redressed.

The use of forged and hardened steel rolls in other than the metal working industries has been rapidly increasing in recent years. Strange as it may seem the largest hardened steel rolls are not used in the steel industry and some are not even used in the metal working industries. In 1930 we made rolls of 44″ body diameter by 144″ long face and 258″ overall. This roll weighed 72,320 pounds and was for rolling aluminum. Figure No. 43 is a 40″ diameter by 191″ face roll weighing 61,300 pounds, for a super calendar in the paper industry.

The wide range of physical properties that can be obtained in steel by variations in analysis and treatments, its high modulus of elasticity and forgeability make it possible to produce rolls of designs for which

FIGURE 42—Roll for forming electric welded pipe.



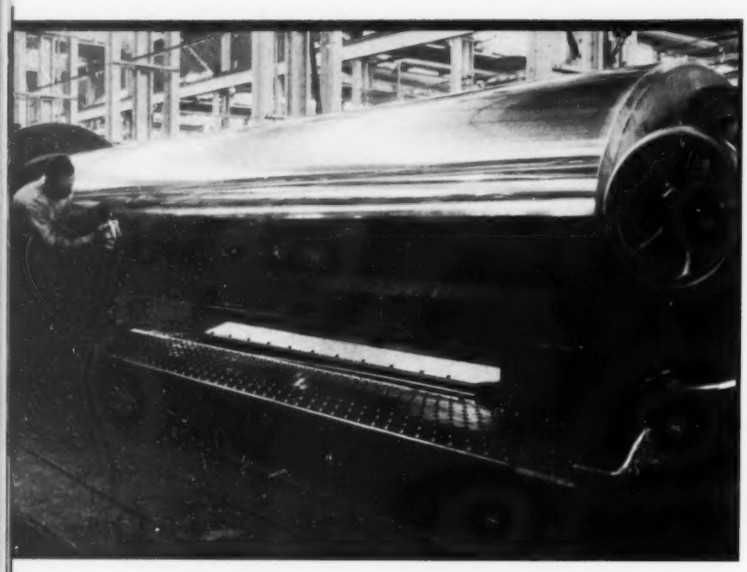
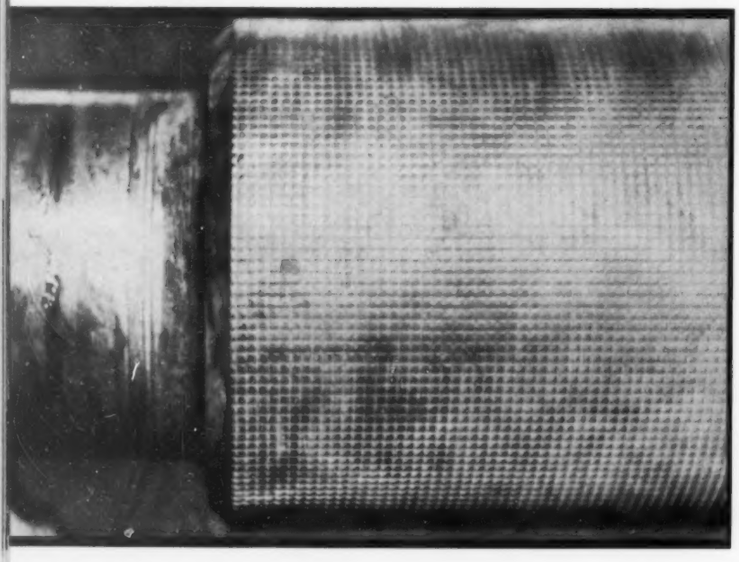


FIGURE 43—This 40″ diameter x 191″ face hardened steel roll weighs 61,300 lb.

other materials can not be used. Hollow rolls for the heating or cooling of the material being rolled are frequently used. When it is desired to thin the walls of rolls to facilitate the flow of heat through them, recourse is had to steel on account of its high strength and great ductility. Rolls of this type may be made as hollow forgings or sleeves on specially designed mandrels with passages under the sleeve for the flow of material to either cool or heat the surface. The production of a hard face in such a roll is no longer the serious problem it was when these rolls were first made.

FIGURE 44—Hardened steel engraved roll intended to produce a waffle pattern on the strip rolled.



In many cases corrosion resistant steels have been applied to overcome attack. All forgeable stainless steel analyses are available. The maximum hardness attainable so far in this type of roll has been about 75 scleroscope. The majority of these rolls are so designed that the minimum amount of stainless steel is used to prevent corrosion, the remainder of the roll being made of carbon steel. This usually reduces the cost of a stainless steel roll to a considerable extent.

In some metal rolling operations engraved rolls are used to put patterns on the material rolled. Large engraved rolls are difficult to manufacture. They are, however, being made as Figure No. 44 shows.

This is a roll for the production of what is intended to be a waffle pattern on the strip being rolled. The great difficulty in the manufacture of rolls of this character is in preserving the engraved surface, preventing them from warping, bending, or going out-of-round during the hardening operations. The application of these rolls is not wide and it does not pay to obtain such a hardened steel roll unless the pattern required is a staple one that will not change over a long period of time. Engraved rolls for the metal industry have to be made with considerable depth of hardness, but where hardened steel rolls are used in industries not engaged in the rolling of metal, the depth of hardness is not so important and rolls of this character are more readily manufactured. The hardness of the pieces varies considerably, again depending upon the service being rendered by the rolls. They can be and are often made with 100 scleroscopic hardness.

DISCUSSION

PRESENTED BY

LOUIS MOSES, Superintendent, Rail Mill and Roll Department, Bethlehem Steel Company, Sparrows Point, Maryland.

S. C. SPAULDING, Metallurgical Engineer, American Brass Company, Waterbury, Connecticut.

J. R. ADAMS, Superintendent, Special Product Department, The Midvale Company, Nicetown, Philadelphia, Pennsylvania.

L. MOSES: Not directly connected with cold reducing mills I may not be in position to discuss hardened steel roll use, abuse or manufacture. However, several questions come to mind after listening to this instructive paper so ably presented by Mr. Adams and Mr. Watson.

It is interesting to note that cold reducing mills are described as having a common characteristic with all other mills. This consists of the earnest pleas of all concerned to the effect that nothing done by mill, or

shop, has contributed to the failure of a roll. We have frequently heard a roller say that a "chunk just fell out" or that a roll "just busted" while operations otherwise were proceeding in a normal manner. The attitude of the mill personnel is improving in this respect, I think. A better knowledge of roll materials and limitations, together with participation in the common problem, creates better understanding between the mill crew and its management. Because of this the life history of a roll is better known without having much recourse to pussyfooting in finding the facts. After several repetitions of mysterious roll failures there is nobody fooled except the individual who tries to hide evidence. Honest admissions by everyone concerned, accompanied with forebearance on the part of the boss, will invariably lead to improvements in practice, adoption of the best roll grade obtainable and confidence and co-operation between roll maker and user.

A chilled-iron roll becomes some 3 to 5 points harder, by scleroscope, through the surface packing which is induced by service in the mill. Does this also occur to hardened steel rolls?

When the screw pressure which is required to produce the minimum gauge possible on a particular mill is still further increased a thicker gauge to the rolled product results. This would indicate that the working rolls are definitely distorted from a true circular shape, somewhat as a bulge would occur to an under-inflated automobile tire. It may well be that this condition will be inadvertently produced during operations and I would ask the authors if they have knowledge of this inducing spallage.

There is no element in the casting of a chilled-iron roll, with swirling molten metal rising in the mold, to induce detail faults leading to a spall. Can it be assumed in equal measure that the cast surface of a corrugated, round ingot is entirely free from segregation which would cause variations in hardness at localized points of the finished roll? Would forging, machining off of the outside surface, and heat-treatment nullify such segregation if it was present? In other words, do spalls occur only from the causes named or do differences in the chemistry, within sharply defined areas such as an experienced spall to adjacent metal, contribute to a failure?

S. C. SPAULDING: First of all we would like to congratulate the authors on their very complete and excellent paper on forged rolls. My discussion will be rather brief because they have covered the ground so thoroughly there is not much one can add.

In the first part of their paper the authors make the statement "when rolls are designed by users or rolling mill manufacturers in collaboration with roll producers best results are obtained and much subsequent grief, both for the user and manufacturer, is avoided". We would agree very emphatically on this point. Whether it is because mill designers have not accustomed themselves to the problems of the manufacture of steel rolls, particularly those connected with the hardening operation, or not, we do not know but we have seen many cases of rolls which, due to limitations in the design of the machine, have to be made with sharp angles, abrupt changes of section, very small necks, and so forth, which seriously affect the life and utility of the roll. A proper understanding of the roll maker's problems by the rolling mill designer would usually eliminate these unnecessary hazards and result in a better roll.

The authors' remarks about methods of testing for hardness are well worth some thought. The scleroscope seems the only instrument available for the purpose. Its successful use requires careful checking, standardization and operation by a careful, experienced operator to insure reliable results. The authors mention the two types "C" and "D" and seem to favor the "D" because of greater convenience and ease of reading. We have done a great deal of work with both instruments and have come to the conclusion that although the "C" type may require more careful and intelligent operation, it makes up for it in greater accuracy and reliability of results. We use the "C" type scleroscope entirely for testing of rolls.

We will heartily second the authors' remarks on the grinding operation. When we receive the roll from the maker it has a highly polished, hard finish surface on it, but what will it be after the first regrinding by the user? There are many damaging effects that can be produced by grinding, as are well brought out by the many fine illustrations in the paper. One point which we believe is not sufficiently emphasized in the paper is the general softening of the complete rolling surface by poor grinding technique. We have seen cases where rolls showing a satisfactorily hard scleroscope reading have had this hardness reduced as much as five points or more in a final grinding operation. The user of rolls might well bear this in mind as he may in this way in his first regrinding operation lose some of the desirable hardness he has paid the roll manufacturer to give him.

We wonder how many users of these rolls realize the importance of checking the surface by the 7 per cent nital etch mentioned by the authors. This becomes most important when the roll surface has become damaged and we wish to grind it clear. Examination of the surface after the finish grinding or polishing, even with a magnifier, will not insure against defects still remaining in the surface.

We find it necessary where a roll has been damaged and it is desired to grind out the damaged spots, that they first be marked for location, then etched after finish grinding. Only then can we tell whether we have them out or whether they must be reground and then re-etched.

The authors mention sleeve type backing up rolls for four high mills with the general recommendation that rolls in this service, 36″ diameter and larger, are usually made up in this way. In a paper by Messrs. Russell and Smith in the British Iron & Steel Institute 1936 Vol. 2, on backed-up mills, they strongly recommend the sleeve type roll. They show them down as low as 24″ in size. In our own experience we have used this type of construction with perfect satisfaction in a 32″ roll. In this case we took a worn out cast steel roll and turned it down to make the arbor on which the hardened steel sleeve was shrunk. The hardness range given of 80-90 scleroscope for backing rolls up to 36″ dia. we are inclined to feel is a little high

(*Please turn to page 73*)

THE *Cornwall* FURNACE

AN EARLY IRON WORKS OF PENNSYLVANIA

By R. D. BILLINGER

LEHIGH UNIVERSITY

BETHLEHEM, PENNA.

▲ THE most productive of the early iron furnaces of Pennsylvania was that of Cornwall. Unique in many ways it still stands in good repair—a splendid industrial monument of the colonial days. It was always a charcoal furnace from its first blast in 1742 until its last in 1883.

The adjoining Cornwall mines of magnetic iron ore, which are still actively producing, had produced until 1890 more ore than any other single mine in the Country.

The Cornwall mines have produced iron ore from 1742 until the present day.

Ten million tons of magnetite were won from them until that time.(1) During the active run of the historic furnace only two family names were associated with it—the Grubbs and the Colemans.

As one motors south from Lebanon to the village of Cornwall four miles distant, you soon notice the beautiful green hills of South Mountain. A closer view reveals brown denuded ridges, the result of surface mining from Iron Hill, Middle Hill, and Grassy Hill—as they were early called. There is about the village an air of the past, picturesque old churches and large homes half hidden in the foliage of well-kept estates. A half mile farther on the road to Ephrata appears a group of buildings which seem to be of a different age. from descriptions I had read I knew that we were near the place I sought. My aged companion was so impressed by the neatness of the structures that he inquired "What church is this?"

The present excellent state of preservation of the Cornwall furnace is due to the wisdom and pride of one of the Coleman descendants, Mrs. Mary Buckingham, who has maintained it until recent years when it was given to the Pennsylvania State Historical Society. From the caretaker Mr. E. M. Patton and the literature cited, the story of the Cornwall Furnace has been learned. The camera shots were taken by the author on several subsequent trips.

About 1735 Peter Grubb moved to Lebanon Township in what was then Lancaster County (now Lebanon County) and acquired several hundred acres of land on which he had discovered pure magnetic iron ore. According to Godcharles(2) he made a famous lease with the Indians "to use the red dirt as long as grass grows and water flows". Records(3) show that Grubb bought three hundred acres of land from William Allen in 1734 and made subsequent purchases from the Penn Proprietors until he controlled all the ore hills.

These mines produced ten million tons of magnetite between 1742 and 1890.

The place was named Cornwall because his father John Grubb had migrated from Cornwall, England in 1692.

Peter Grubb and his brother Samuel built other furnaces to utilize the easily obtained ore. One of these was the Hopewell Forge on Hammer Creek.

Convenience of location of raw materials was much more important in colonial times than today. Cornwall was fortunate in having limestone quarries near the ore banks, and charcoal was obtained from the timber of the nearby hills. Red sandstone of the region was used in the furnace construction and also in the walls of the adjoining and nearby buildings.

The furnace is the center of a large T-shaped group of buildings consisting of cast-house, blower shed and sleeping quarters for workmen. (Figure 1.) The present furnace is really the enlarged one of 1845. Its outside dimensions are 28 feet square at the base, 32 feet high, and 20 feet square at top. The earlier furnace of the same height has a base 21½ feet square and the top was 11 feet square.[4] Its production was 20 tons of bar iron a week. Blast was supplied by a huge 20 foot bellows operated by water power. Water from Furnace Creek filled a small reservoir, from which it was piped to an over-shot water wheel. Figure 2 shows the remains of an antique water pipe over grown by a huge sycamore, and Figure 3 shows the stone culvert through which the water issued.

From the casting floor, the front view of the furnace is shown in Figure 4. Diagrams of similar furnaces[5] of the period are shown in Figures 5 and 6. The stack of splendid masonry is made of carefully hewn blocks of native sandstone. Iron braces supporting the walls are said to have been brought from England. The interior of the stack is lined with a wall of fire-brick. The earlier furnace may have employed a fine grained sandstone lining. A flashlight view down into the interior of the stack is shown in Figure 7. The inner dimensions vary from 3 feet in diameter at the hearth

FIGURE 1—(Below)—Plant buildings are reminiscent of medieval architecture.

FIGURE 2—(Center)—Remains of an old water pipe are overgrown by a large sycamore.

FIGURE 3—(Right)—Stone culvert through which waste water flowed.

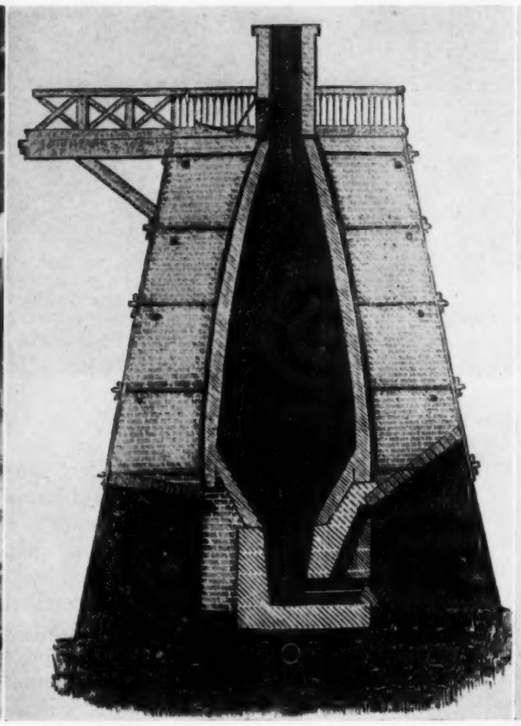


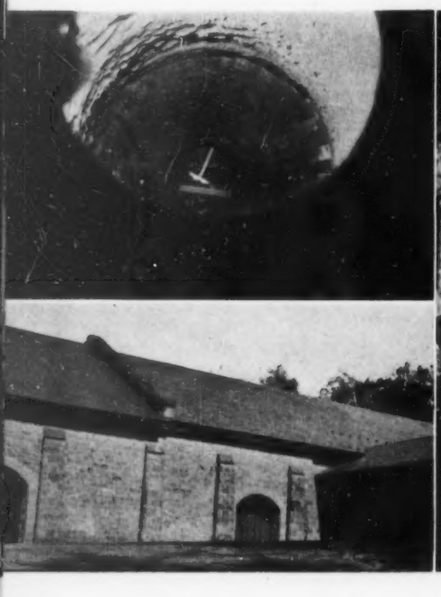
FIGURE 4—(Upper left)—Front view of the furnace from the casting floor.

FIGURES 5 and 6—(Upper center and right)—Diagrams of similar early blast furnaces.

FIGURE 7—(Below)—View down into the interior of the furnace stack.

FIGURE 8—(Below)—A stone archway connects the main floor with the furnace top. Furnace gases pass through the smaller arch into a brick chimney.

FIGURE 9—(Below)—Stone building used for storing charcoal.



to 7 feet in the bosh. The output of this furnace was forty tons a week.

Around the stack by winding stairs and up to the fourth floor (rear) is the charging room. Beneath a fine arched roof, which does credit to its builders, is kept the old stoker's gear. Two-wheeled hand carts of varying size for ore and charcoal; baskets for smaller charges; the platform weighing scale; a notched board with pegs to tally the charges; pushing tools and bars to shove materials into the circular charging hole in the floor directly over the stack. A stone archway connects the main floor with the stack top (Figure 8), and a smaller arch carried off the furnace gases into a brick chimney surmounting the main stack.

Connected to the charging room by a covered drive is a long stone shed (Figure 9) used for storing charcoal. Built as if for the ages these buildings are in excellent repair.

The charcoal fuel problem created quite an industry in itself. At times timber was brought in from twenty miles distant. Numerous indeed must have been the mounds of slowly smoldering logs, packed down with sod for the conversion into charcoal.

The steam engine installed in 1845 to furnish power for the cold air blast is shown in Figure 10. It is a 20 horsepower, single cylinder engine with a flywheel 9 feet in diameter. Steam for it was obtained from two boilers (21 x 3 feet) heated by hot gases from the stack. The engine is geared to a huge wooden wheel (24 feet diam.) in an adjoining blower room. This wheel on a 13½ foot shaft has connections with wooden drive rods which could operate pistons in two overhead blowing cylinders. A blast of about two pounds pressure was thus obtained. Ingenious but ponderous wooden equipment for so small a blast, but a distinct advance over the earlier bellows system.

On the death of Peter Grubb in 1754 the estate went to his two sons Curtis Grubb and Peter Grubb, Jr. These men were both Colonels in the Continental Army. They supplied cannon and shells (Figure 11) as well as serving actively in the field. A copy of an interesting notice (Figure 12) is painted on the wall of the engine room. This shows the importance of Cornwall as the "hub of the iron trade". Travellers from many lands visited the famous mines and furnace. Acrelius, authoritative writer (6) of the period, describes the mine as "rich and abundant, forty feet deep, commencing two feet under the earth's surface. The ore is somewhat mixed with sulphur and copper. Peter Grubb was its discoverer. Here, there is a furnace which makes twenty-four tons of iron a week, and keeps six forges regularly at work—two of his own, two belonging to Germans in the neighborhood, and two in Maryland. The pig iron is carried to the Susquehanna River, thence to Maryland, and finally to England. The bar iron is sold mostly in the country and in the interior towns; the remainder in Philadelphia. It belongs to the heirs of the Grubb estate, but is now rented to Garret and Company".

In 1786 Robert Coleman bought one-sixth of the Grubb estate and by subsequent purchases obtained an additional four-sixths of the valuable property. Through several generations of each of these two families ownership and management was controlled. Coleman, Irish born came to Philadelphia in 1764 and early became engaged in the iron trade. Before entering Cornwall he had experienced at Quitophilla Forge, near Lebanon, at the Salford Forge, near Norristown and later purchased the Elizabeth Furnace.(7) He was a member of the General Assembly in 1788, and later an associate justice for many years.

Coleman made Elizabeth his home, where he lived with his wife Anne Old—herself the daughter of an iron master. His interests were great and he was to earn the reputation of being the most noted iron master in Pennsylvania.

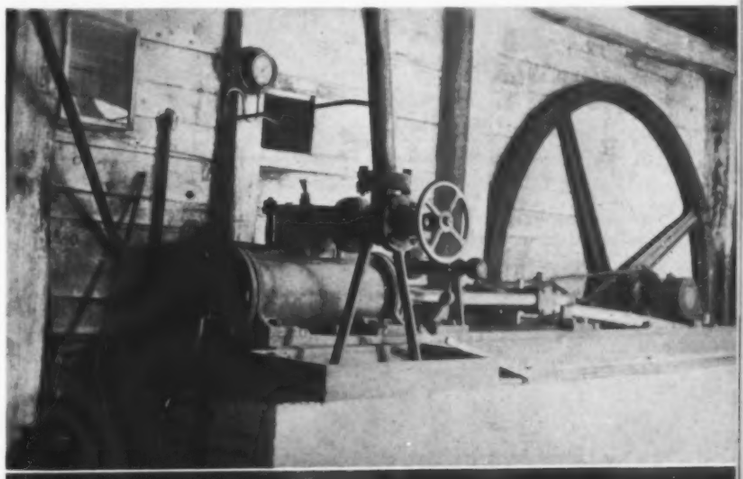
The Coleman name continued in the iron business at Elizabeth, Cornwall and Lebanon through four generations. Grandsons Robert and George Dawson Coleman erected the Lebanon furnaces in 1846, and there introduced anthracite coal and hot blast. There were other furnaces at North Cornwall and Lebanon, much improved and of greater productivity, but this is not their story. Beside the owners, who were not always the active managers, many names were associated with the iron trade. Local history remembers a few like Jackson, Wilhelm and Grittinger over a long span of years. The Pennsylvania Steel Company entered the region about 1901, and since the days of the World War, Cornwall Mines have been owned and operated by the Bethlehem Steel Company.

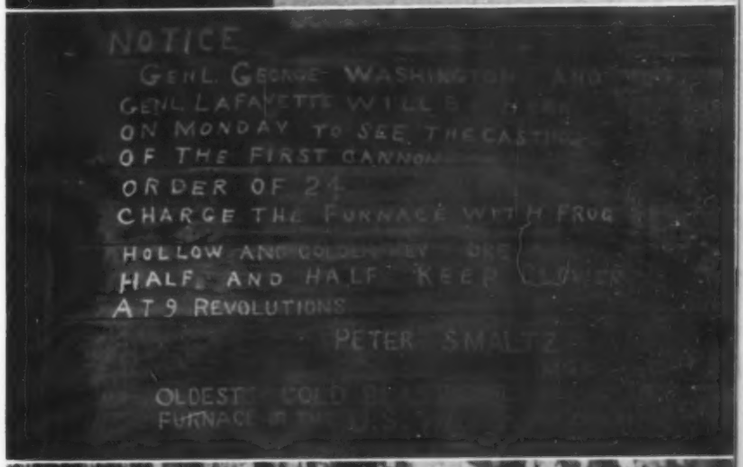
After 1865 when the Bessemer process began to make a success in this Country the value of Cornwall ores in this field became known. Outside of the Cornwall mines, all the acid Bessemer ores were practically confined to the Lake Superior region.(8) John Fritz then General Superintendent of the Bethlehem Iron Company, states "at that time we were the only people who knew how valuable the Cornwall ore was. The other Bessemer makers were, in a general way, fearful of the sulphur, but we had learned that for rails and some

FIGURE 10—(Top)—Cold air blast was furnished from this 20 hp. steam engine.

FIGURE 11—(Bottom)—Cannon and balls formed an important part of the early production of this furnace.

FIGURE 12—(Center)—Copy of a notice painted on the wall of the engine room.





FIGURES 13 and 14—The mines present a rolling vista of deep open pits and rocky hills.

other purposes the sulphur was practically quite harmless, and that we could use the Cornwall ore to great advantage up to one-half of the mixture."(9) His recommendation that his Company make a long time contract with the Cornwall people required many years for approval.

In the language of the geologist (10) the mines at Cornwall are described as "a bed of soft magnetite with some pyrite found between Cambrian limestone and Triassic shales and against igneous dikes. Their age has been placed as both Cambro-Silurian and also Triassic, and whether they represent metamorphosed pyritiferous shale or limonites is also unsettled. The ore runs from 40 to 55 percent iron and usually under .02 per cent phosphorus, but is rather high in sulphur and silica". This is the same "red dirt" which Peter Grubb began to dig some 200 years ago—"pay dirt" which has made Cornwall the most famous iron mine in the Country, and the longest in continual operation. Its deep open pits (Figure 13) and rocky hills (Figure 14) bear witness to the ardor and zeal of men who live in the quaint stone houses of Mine Village.

1—*The Mineral Industry*, Vol. 1, p. 275, The Scientiffc Publishing Co., New York, 1893.

2—GODCHARLES, F. A., "*Pennsylvania, Political, Gov. ernmental, Military and Civil*", Vol. 4, p. 260, The American Historical Society, Inc., New York, 1933.

3—LONGACRE, A. M. "*Forges and Furnaces in Provincial Pennsylvania*", p. 84, Pennsylvania Society Colonial Dames of America, Philadelphia, 1914.

4—VIVIAN, C. H. "*A Blast Furnace Nearly 200 Years Old*", Compressed Air Magazine, 39, 4361, 1934.

5—BOWER, ELI, "*The Pictorial Sketch-Book of Pennsylvania*", p. 111-12, W. P. Hazard, Publisher, Philadelphia, 1852.

6—SWANK, J. M., "*History of the Manufacture of Iron*", p. 139, privately published, Philadelphia, 1884.

7—"*Colonial and Revolutionary Families of Pennsylvania*," vol. V, p. 461, The Lewis Historical Publishing Company, New York, 1934.

8—"*The Mineral Industry*," vol. 3, p. 450, 1895.

9—FRITZ, JOHN, "*The Autobiography of John Fritz*", p. 162, John Wiley and Sons, New York, 1912.

10—RIES, HEINRICH, "*Economic Geology of the United States*," p. 256, The Macmillan Co. N. Y., 1907.

Modern pit mining equipment has replaced the antiquated methods used in the days of Cornwall furnace.

ADAMS' DISCUSSION

(*Continued from page 67*)

Something around 75 to 80 would appeal to us as better suited to this service.

We do not find that the authors have mentioned high speed steel as a material for rolls. High speed steel, both of the 18-4-1 and molybdenum type, is used for the manufacture of rolls. Its use, naturally, is limited to the smaller sizes of rolls. One field where it has found quite a place is in work rolls for Steckel mills. Another material which might be mentioned is tungsten carbide. While this material, as far as rolls go, is still very much in the experimental stage, we understand there have been a few small rolls made up for trial. What its possibilities for the future are, who can say.

This paper has shown us users very forcibly what can happen from abuses in grinding, wrecks on mills, slippage, overheating of bodies and journals, and so forth, and it is for us to heed and correct them. The roll maker too has a responsibility in the production of better rolls, rolls more suitable for the abuses (if we should so call them) of every day use.

The authors give a type analysis of hard steel rolls. This type analysis and the general methods of manufacture of these rolls have been standard for many years while we must admit the service rolls are called on to perform becomes increasingly more severe. We feel the future calls for the development of a better, hard steel roll, which calls for a possible change in composition or manufacturing methods, or both. We have mentioned high speed steel and carbide; these are possibly not the answer Russell & Smith express it in the conclusion of their paper by calling for the development of a more thermally stable roll material.

We would like to leave this as a final thought; that it is the task of the roll maker not only to perfect the roll of today but to produce a better roll for tomorrow, better able to withstand the so-called abuses to which we must subject them.

J. R. ADAMS: In reply to Mr. Moses' remarks we wish to state that we do not wish to imply that evidence pertaining to the possible cause of failure of rolls is suppressed or withheld by the mills. This has not been our experience. We do however wish to point out that in many cases incidents occurring during rolling are regarded too lightly by rolling mill operators at the time they occur and quite naturally are honestly forgotten when the failure of the roll takes place. The greater attention rolling incidents have received in recent years has brought forth information leading to marked improvements in rolling operations as well as modifications in composition and manufacture, both of which have materially increased the usefulness of steel rolls to mill operators.

Forged steel rolls do increase in hardness in use and this increase is usually greater with the softest rolls. The higher hardness rolls also increase in hardness a detectable amount but it is not very great.

In reply to the question as to whether increase in pressure beyond that required to produce minimum gage on a particular mill will bring about spalling, the theory advanced by J. D. Keller on this subject indicates that such may be the case. It is the experience of the authors that excessive pressure is one of the quickest ways to bring about spalling but excessive pressure may occur before the minimum gage is attained, according to Keller's mathematical analyses, for the design of the particular roll under consideration.

That segregation in a corrugated ingot may be responsible for spalling the authors believe is not the case. Segregation occurs in all cast ferrous alloys and forged steel roll ingots are no exception. The authors have, however, split and examined numerous ingots used to produce forged steel rolls and have not found segregation in a position that could account for spalling of a roll, even in the deepest spalls they have observed. An ingot badly segregated in the center usually manifests itself by violent disruptive failure in hardening and, more rarely, by similar breakage almost immediately after the roll is put into service, but such failures are entirely distinct from spalling.

Referring to Mr. Spaulding's comments, the authors appreciate his kind remarks and are gratified to find they are in agreement on so many points with such an authority on this subject. The question of which type of scleroscope to use is one that each must answer for themselves since there appears to be no positive answer respecting their relative merits. The roll manufacturer has a great deal more scleroscoping to do than any user and for reasons of convenience and speed we prefer to use the "D" type of instrument, believing that it is as accurate as the "C" type instrument when used under proper conditions. The remarks of Russell and Smith on backing-up rolls are apparently based on experience in one mill, rolling non-ferrous material. Whether they had any extensive experience with one piece backing-up rolls does not appear. Since their experience with backing-up rolls was apparently quite limited we do not think their judgment can be considered final. We have had 56″ diameter backing-up rolls made in one piece in successful service in Europe for some time. We prefer the higher hardness of 80-90 scleroscope in the smaller back up rolls because the intensity of local stress in the face is higher with the smaller diameters and they wear better. We are aware of and make high speed steel rolls for Steckel Mills and apply them in other mills under very special conditions but their use is quite limited due to cost and practicability of manufacture. Tungsten carbide is being tried but whether it will ever be a practical roll material for even small rolls is not as yet determined. The roll makers recognize that there are still advances to be made in forged steel roll materials and considerable time is being spent on the problem. The manufacture of hardened steel rolls has advanced considerably in the last ten years or the present backed-up mills would not be able to operate as they are doing today.

LOW VOLTAGE *Rectifiers for* INDUSTRIAL REQUIREMENTS

By G. E. STOLTZ and J. H. COX

WESTINGHOUSE E. & M. COMPANY

EAST PITTSBURGH, PENNA.

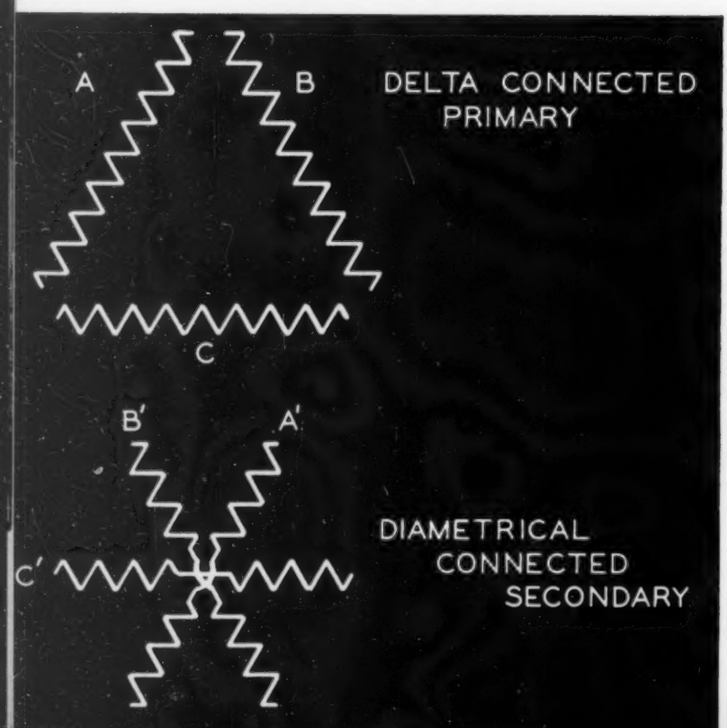
Presented before the A. I. & S. E. Annual Convention, Cleveland, O., September 27, 28, 29, 30, 1938

▲ DUE to the fact that it is more economical to generate and transmit alternating current power than direct current power, the trend in every industry is to use alternating current wherever the application permits.

The textile industry is able to use alternating current equipment almost exclusively, while the steel, mining and material handling have a number of applications that cannot be properly handled by alternating current motors, but require direct current equipment.

During the early years of electrification of the steel industry, it was the practice to use direct current motors on cranes, mill auxiliaries and certain machine tools. On main mill drives with the exception of reversing mills, alternating current type motors were used and quite an effort was made to continue this practice by the use of Kramer and Scherbius sets where adjustable speed was required. As electrification in the steel industry continued, operators began to appreciate the greater possibilities in electric drive over that of the steam engine. These original units served their purpose for a while, but in time operators began to see where still greater flexibility of driving equipment would permit them to reduce their costs or improve their methods of rolling. The new demands of the driving equipment were such that direct current motors with motor generator sets have been used instead of a-c. adjustable speed sets, regardless of the fact that the cost is greater and efficiency lower. It is a matter of record that the requirements in the steel industry are becoming so exacting that the tendency today is growing more to the use of direct current equipment rather than less. This is illustrated by its use on continuous hot and cold sheet and strip mills, its application on flying shears, runout tables, and the recent introduction of variable voltage equipment having shovel type characteristics on main blooming mill auxiliaries.

FIGURE 2—Diagram of transformer windings and connections for six-phase rectification.



Conversion of alternating current to direct current power has been accomplished by the use of rotary converters and motor-generator sets. Although motor-generator sets cost more and are not as efficient, the independence of the d-c. voltage from the a-c. and the possibility of using the motor-generator sets for variable voltage control has virtually made them standard for steel mill service.

While the steel industry is one of the most progressive in adopting new ideas, electrical manufacturers prefer to first try new apparatus in other industries if this is at all possible. The costly interruption in service as obtained in the steel industry no doubt accounts for this attitude. It is one thing to have available appa-

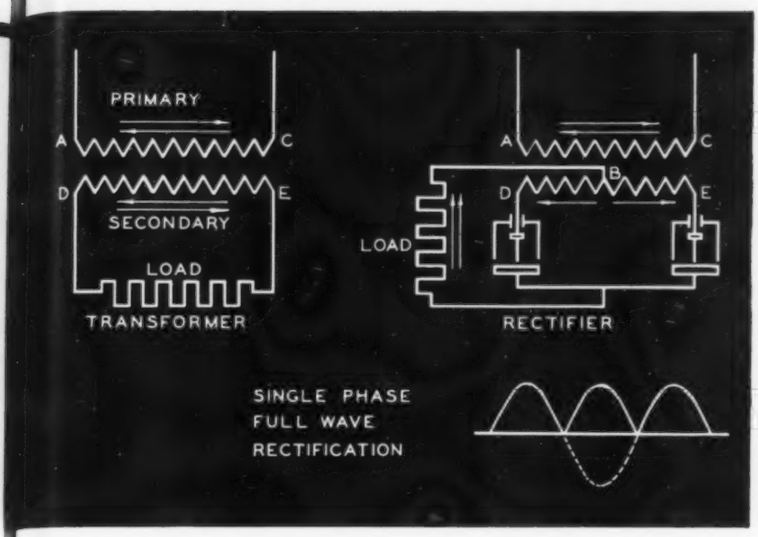


FIGURE 1—Comparison of a standard single phase transformer diagram with that of a single phase full wave rectifier.

ratus that is theoretically correct, and another to have equipment that has reached a degree of perfection that assures continuity of service which is only attained after a period of experience.

During the last generation the mercury arc rectifier has been undergoing the process of development to the point of becoming a thorough going dependable and finished product. Considerable experience has been gained in other industries and it is our feeling that we have reached the stage where the steel industry as a whole should now consider its installation. This is particularly true due to the recent introduction of what is termed the "Ignitron" type of rectifier using synchronous ignition of the arc for each anode. This design materially reduces the losses as obtained in a conventional rectifier due to a decrease in the voltage arc drop, and tends toward greater continuity of service due to the separation of the anodes in individual tanks. The arc drop of a rectifier is relatively constant so the higher voltage applications are the more efficient. This recent reduction in losses makes the Ignitron rectifier attractive at 250 volts, which, in the steel industry, is the logical application for the first installations.

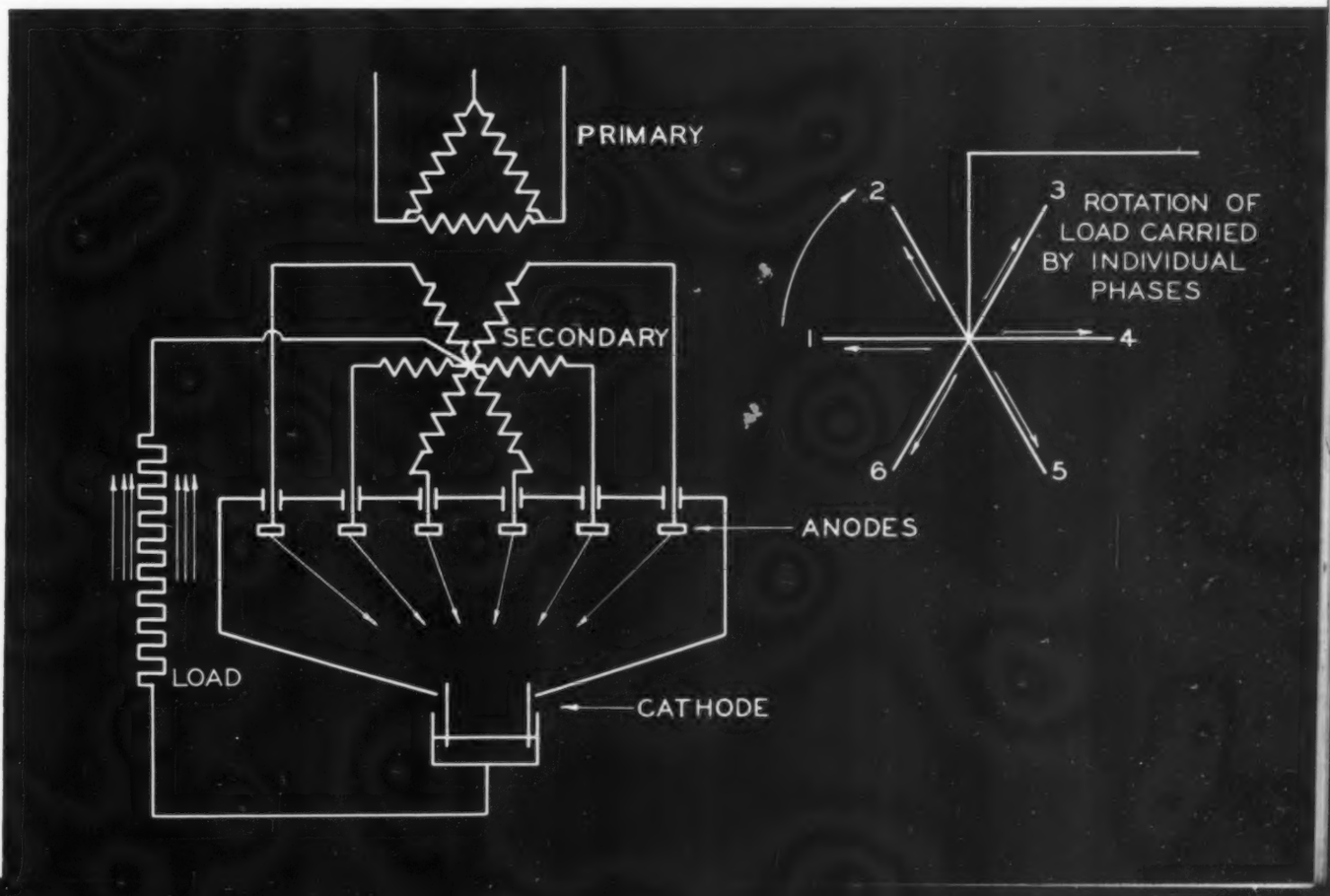
RECTIFIER CIRCUITS

One of the simplest practical forms of full wave rectification consists of a single phase transformer with a valve element in each leg of the secondary. The return circuit is connected to the mid-point of the transformer winding.

With a center tap rectifier the design of the secondary differs from a standard transformer, since at any instant load is carried by one-half of the winding. This is illustrated in Figure 1, which compares a standard single phase transformer diagram with that of a single phase full wave rectifier.

As the current in the primary of a conventional transformer flows from left to right, that is, from A to C, the current in the secondary is flowing from right to left, that is, from E to D. This latter current circulates through the entire secondary of the transformer, the

FIGURE 3—Diagram of a six-phase rectifier, showing connections and rotation of load carried by individual phases.



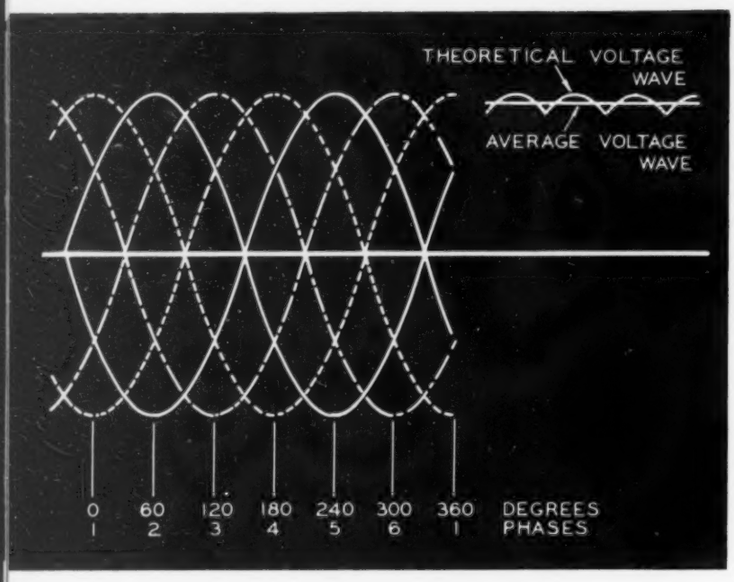
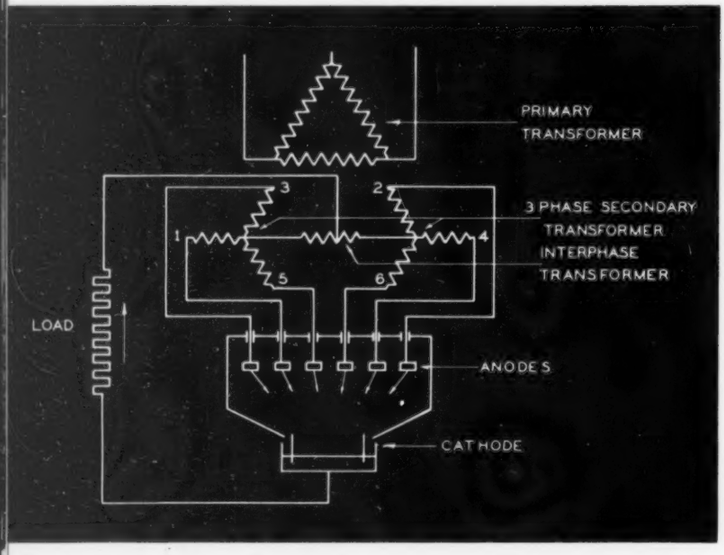


FIGURE 4—Six-phase rectification produces a uniform direct current voltage wave.

load, and the leads between the secondary of the transformer and the load. When the current in the primary reverses and flows from C to A, the current in the secondary flows from D to E.

The same thing is true when a transformer is used in connection with a center tap rectifier except the rectifier limits the flow of the current in the secondary of the transformer to one-half its winding. As the current in the primary of the transformer flows from left to right, that is, from A to C, a voltage is set up in the entire secondary of the transformer from right to left, that is, from E to D. A rectifier permits flow of current in one direction only and in this instance we have shown the rectifiers permitting the current to flow away from the transformer. With a flow of current in the primary of the rectifier transformer from A to C, the secondary current will only flow in the left half of the winding, that is, from B to D, then through the rectifier, the load, and back to the neutral connection at B. The rectifier to the right will not permit current to return to the transformer connection E so that the winding from E to B is idle during this half cycle. When the current reverses in the primary of the transformer, that is, when it is flowing from C to A, the voltage setup in the secondary winding is from left to right, that is, from D to E, but since current cannot flow to the transformer through the left rectifier during this half cycle, the current flows from B to E through the rectifier, the load, and back to the neutral at B again.

FIGURE 5—The use of two three-phase secondary windings for six-phase rectification reduces transformer heating.



With single phase rectification the current through a resistance load is direct current in the form of half waves as is shown above the horizontal line in the diagram to the right in Figure 1. Such a wave is satisfactory for many small power applications, but for large outputs it is preferable to have direct current voltage of a more uniform value than would be obtained by single phase rectification.

To obtain such a result transformer windings as shown in Figure 2 are employed. The three primary phases are joined at their terminals to form a delta to receive the power supply from a three phase source.

Each of the primary phases has a corresponding magnetically coupled secondary in which is induced voltages in the same phase position as its primary winding. Phase A′ of the secondary physically parallels phase A of the primary. Since the primary voltages are displaced 120 degrees, it follows that the secondary voltages are also 120 degrees apart.

As has been explained and is shown in Figure 1, a mid point tap in the transformer secondary is used as the return terminal for the rectified load circuit. In a similar manner, the rectified return circuit is brought to a common terminal connected to the mid point of each secondary as is shown in Figure 3.

Due to the mid point of each winding being connected together the phases cross each other resulting in six end terminals spaced at 60 electrical degrees. This constitutes a six phase secondary circuit for a six anode rectifier. Pulsating current in the individual phases of such a transformer sets up a rotating maximum voltage passing from one phase to another. For any given instant the phase which is producing the highest voltage carries the entire load through its anode to the cathode, then through the load, and back to the neutral of the transformer. This means that each anode is carrying full load capacity for one-sixth of the time and a fairly uniform direct current voltage wave is produced as is shown at the top of Figure 4. With reactance in the secondary and load circuit, this wave actually has little or no ripple.

While this arrangement produces a satisfactory direct current wave, a reduction in the heating of the transformer can be obtained by the use of two 3 phase secondary windings tied together at their neutrals by an interphase transformer as is shown on Figure 5. By

alternately stepping from one transformer secondary to the other, a rotating voltage is produced similar to that shown by the equipment used in Figure 3. However, in this instance each phase carries current one-third of the time so that current is being obtained from two anodes at any given instant instead of one.

Figure 6 is a graphical representation of the voltage obtained from these two secondaries. It can be assumed that the left-hand secondary produces the full line wave while the right-hand secondary produces the values indicated by the dashed curve. The average of the two is the output voltage, the interphase transformer acting as a step-up auto-transformer when the terminal voltage of one phase is below this, and as a reactance when the terminal voltage of the active phase in the other secondary is above this value. As indicated, this average output voltage is just as smooth a curve as obtained from the six phase transformer. It, however, has the advantage that the heating in the windings of the two 3-phase secondaries is but 70.7 per cent of that obtained in a six phase transformer as shown in Figure 3. This can be illustrated by the charts shown in Figure 7 where we have assumed a smooth and constant flow of current from each anode when it is in service rather than the rounded waves with some overlapping as is obtained in actual practice. The root-mean-square of 50 per cent current in two three-phase secondaries for one-third of the time is 70.7 per cent of the root-mean-square of 100 per cent current in a six-phase secondary for one-sixth of the time. This two three-phase secondary transformer arrangement has now become standard for both the Ignitron and conventional rectifiers.

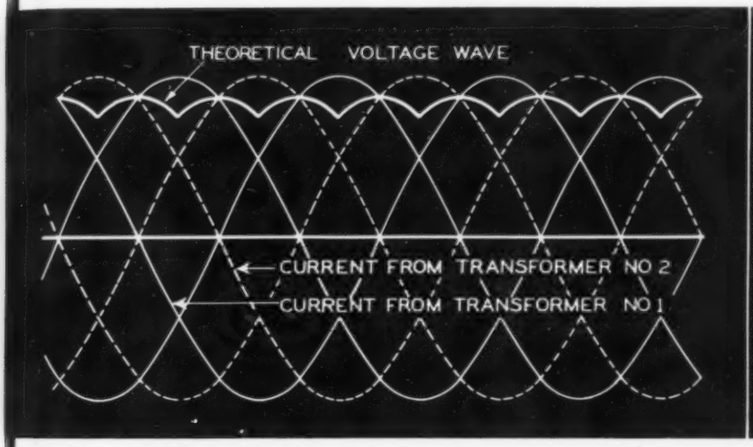


FIGURE 6—Graphical representation of voltage obtained from six-phase rectification using two three-phase transformers.

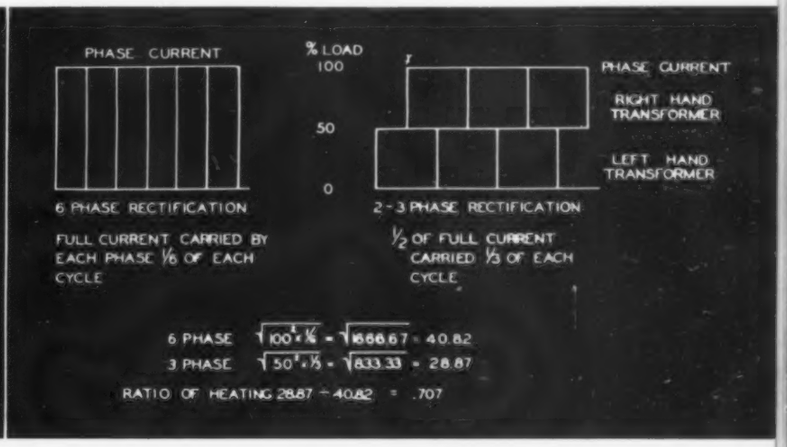

PHASE CURRENT
% LOAD
100
50
0
PHASE CURRENT
RIGHT HAND TRANSFORMER
LEFT HAND TRANSFORMER
6 PHASE RECTIFICATION
2-3 PHASE RECTIFICATION
FULL CURRENT CARRIED BY EACH PHASE 1/6 OF EACH CYCLE
1/2 OF FULL CURRENT CARRIED 1/3 OF EACH CYCLE
6 PHASE √100²×1/6 = √1666.67 = 40.82
3 PHASE √50²×1/3 = √833.33 = 28.87
RATIO OF HEATING 28.87 ÷ 40.82 = .707

FIGURE 7—Comparison of heating between six-phase and two three-phase rectification.

CONVENTIONAL RECTIFIER

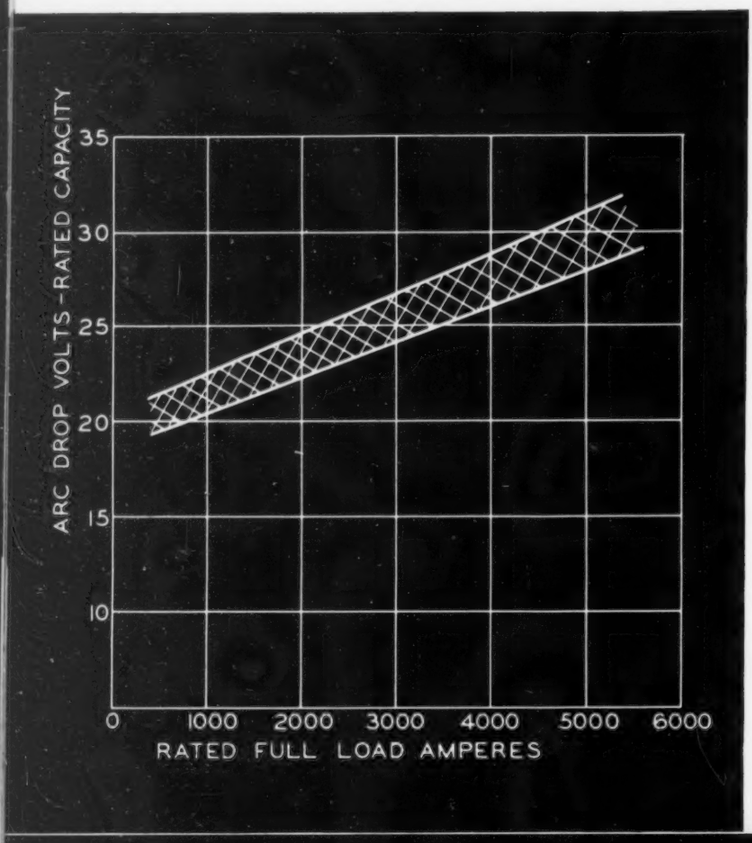
Conventional metal tank mercury arc rectifiers consist essentially of a steel tank fabricated of steel sheet welded with vacuum tight welds, with an insulated pan at the bottom for the mercury cathode and six, sometimes more, graphite anodes connected to the anode terminals through vacuum-tight insulating bushings. The unit uses rubber with protecting iron bands for the large vacuum-tight joints. The anode bushings are porcelain, sealed vacuum-tight to the tank with copper rings soldered directly to the porcelain. A starting anode is provided, which may be caused to make and break contact with the mercury cathode by means of a solenoid outside the tank. After the cathode spot is formed, it is maintained by a continuous small current to a pair of exciting anodes.

Any wearing or erosion is negligible. The small amount of leakage of gas causes the accumulation of a proportional amount of compounds of mercury. When this progresses to a point where operation is affected, it is only necessary to open the tank, clean it and refill the cathode with clean mercury. Experience indicates that the period between cleanings is at least 10 years.

Since high power rectifiers must be water cooled a corrosion problem arises, as the arc chamber must be made of steel. Other inexpensive metals react with mercury. However, this problem has been eliminated by the use of heat exchangers which permit the treatment of the water passing through the rectifier to render it non-corrosive.

It is to be noted that the anodes are removed from direct exposure to the cathode and are each encased in a steel shield open at the bottom but with grids to break up the opening into several smaller passages, for the purpose of avoiding arc-backs.

It is obvious that in a larger tank with larger or more anodes, the distance between anodes and cathode will be increased. The amount of shielding must be increased. Both these effects result in a still higher arc drop in the larger tanks with a corresponding lower efficiency. Figure 8 illustrates this influence of tank size and shows the range of arc drop for tanks having various ratings. The arc drop varies from 20 to 30 volts. A conventional rectifier having a rating of 1000



amperes would have an arc drop of approximately 22 volts while one of 5000 amperes would have a drop in the neighborhood of 29 volts.

ARC RECTIFICATION

Mercury arc rectifiers, both of the conventional and Ignitron types, depend for their operation on the rectifying property of an arc in a low pressure gas. Under normal conditions, gases are insulating, but under certain conditions in which the gas molecules are broken up into electrons (negatively charged ions) and protons (positively charged ions,) gases may become highly conducting. The motion of the charges, principally the electrons, constitutes the flow of current.

However, if a pair of neutral electrodes as illustrated in Figure 9 are inserted in an ionized gas and a potential difference applied, only a small current will flow, even though the gas is highly ionized. This is due to the fact that electrons (negative ions) may enter a con-

FIGURE 8—Arc drop voltage in rectifiers is materially influenced by tank ratings.

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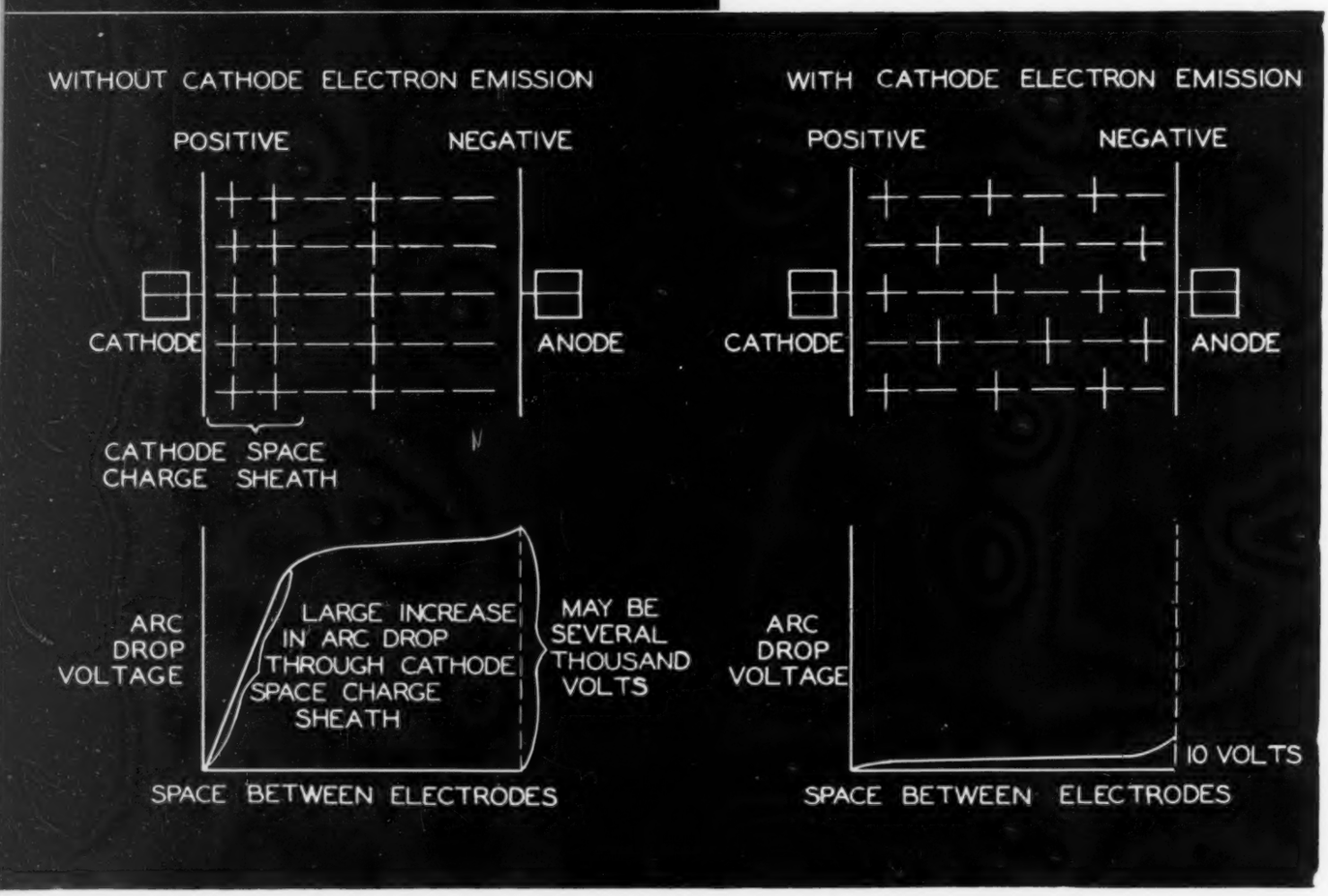
FIGURE 9—Diagram of ion field and voltage gradients between anode and cathode in gas-filled space.



ductor readily, but it requires special conditions to induce them to leave a conductor. Therefore, in the case of the two electrodes in the ionized gas with a potential between them, all of the electrons will be withdrawn from the region around the cathode (shown at the left of the left-hand sketch Figure 9) and the positive ions will fill the space. Due to the relatively low mobility of positive ions they will conduct only a small current even with a potential high enough to ionize the gas by collision. This positive ion filled space is called the "cathode space-charge sheath", and most of the potential between the electrodes is found to be across this sheath. This was formerly called the "cathode reluctance". This condition of high voltage with currents of the order of milliamperes is called a glow discharge.

If some means is established by which electrons (negative ions) may be emitted from the cathode (at left), these electrons neutralize the field set-up by the positive ions in the cathode space charge sheath, and large currents (within the limits of the cathode to produce electrons) may be carried between the electrodes with a relatively low voltage difference as shown by lower right-hand curve Figure 9. Thus, it is obvious, that if conditions are established at one electrode so that it will emit electrons and these conditions avoided

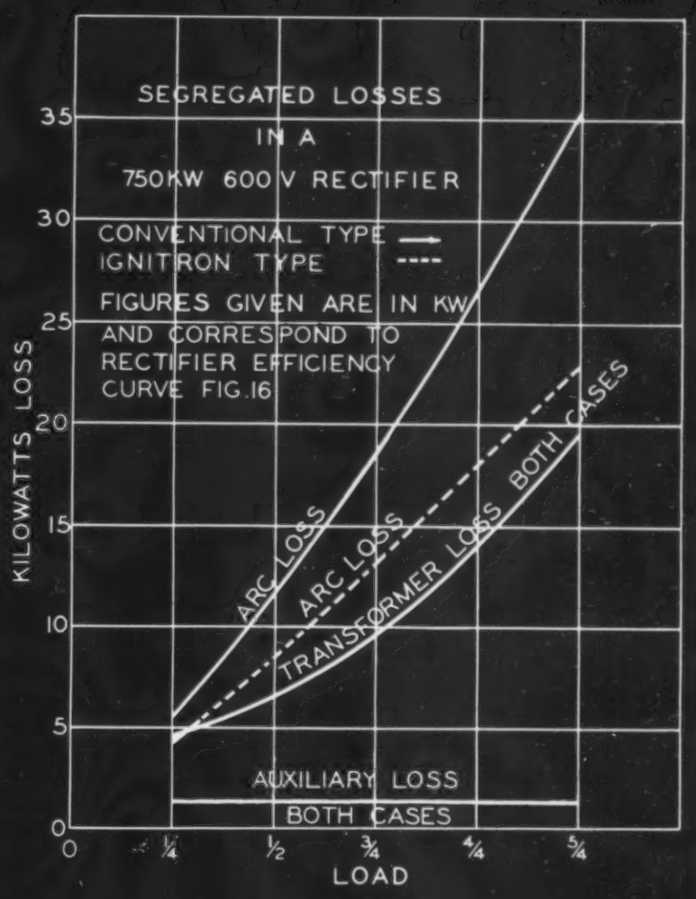


FIGURE 10—(Top)—Rectifier losses occur as iron and copper loss in the transformer, as arc drop in the rectifier, and as rectifier auxiliary consumption.

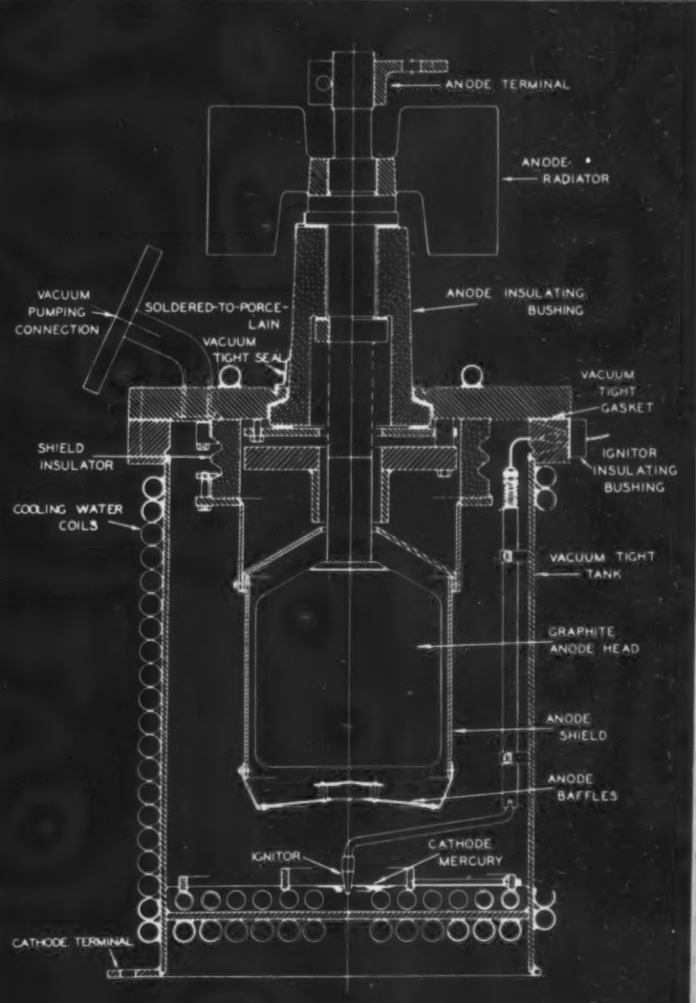


FIGURE 11—(Bottom)—Cross section of Ignitron rectifier, which provides a separate tank for each anode.

at the other electrode, we have a undirectional conductor, or a rectifier. If the ionized condition of the gas is maintained by some outside means, there is no lower limit to the voltage required to pass considerable current. If, however, the discharge itself must maintain the ionization, a cathode voltage drop sufficient to give the electrons enough energy to ionize molecules by collision will be developed. For mercury vapor, this is about 10 volts.

There are two general methods by which an electrode may be made to emit electrons. If metals are heated to a sufficiently high temperature they will emit electrons. For tungsten this temperature is over 2000 degrees Centigrade. For a metal coated with certain oxides, this temperature may be as low as 700 to 800 degrees. However, cathodes of this type are fragile, they are limited practically to about 100 amperes, and they have so short a life that renewal costs are a consideration.

The other method of obtaining electrons from the cathode or at least of neutralizing the cathode space charge sheath, is to maintain what is called the "cathode spot" of an arc. There are various theories to explain phenomenon of the cathode spot of an arc, which we will not discuss here. However, it is an experimental fact that if a current density of several thousand amperes per square centimeter is set up at a cathode, this

spot will be electron emitting. Such a spot is not self forming and must be set up as by breaking a contact or by the method used in the Ignitron. Such a cathode spot requires the order of 10 volts to maintain the required conditions for electron emission.

The high current density in the cathode spot with the consequent heat concentration—the product of the 10 volts and the current conducted—presents a practical difficulty of losses and temperature. Any material under this condition will boil. It so happens that mercury is not only liquid at practical working temperatures—so that boiling may be permitted and the vapor condensed and returned to continuously reconstruct the cathode—but at these same temperatures the vapor pressure of mercury is such as to provide the most favorable molecular density for arc conduction. Thus, a mercury pool constitutes an ideal cathode for a heavy current rectifier, as it has unlimited life, it appears to have unlimited current capacity, and provides the gas for the arc path.

ARC-BACK

It might seem that to construct a high power rectifier it would only be necessary to provide a mercury cathode, with some form of auxiliary electrode for striking and maintaining continuously a cathode spot upon the mercury, and place nearby another electrode to function as the anode in the main discharge. By placing the anode close to the cathode, the arc drop would be only 10 volts or even less. If this were possible, the anode would only need to be large enough to radiate the heat given to it by the electrons without reaching too high a temperature, and a rectifier for a thousand amperes and a thousand volts would be only a few inches in diameter.

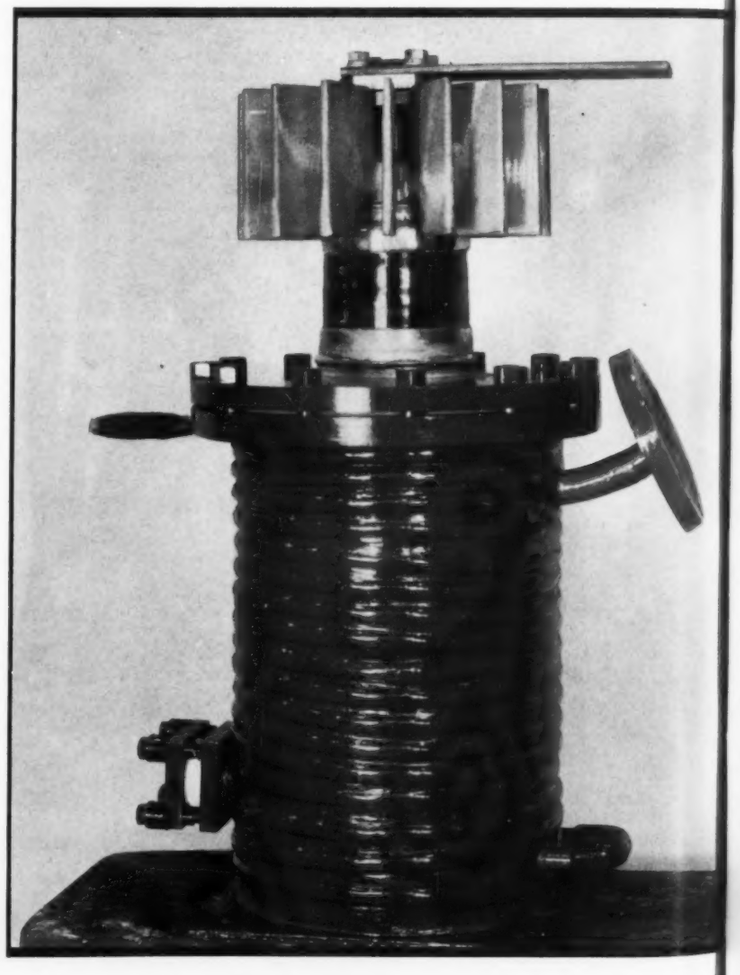
Unfortunately, and quite unexpectedly so far as theory goes, the phenomenon known as "arc-back" enters the picture. Although, as explained above, a cathode spot from its nature cannot be self starting, it is found that in simple structures, occasionally a cathode spot will spontaneously appear on an anode when it is bearing reverse voltage and should be maintaining its cathode space charge. Such an appearance of a cathode spot, or an arc-back, constitutes a near short-circuit in the reverse direction, and, since when once formed a cathode spot is maintained so long as current is conducted through it, requires the automatic opening of protecting circuit breakers. If graphite is used for the anodes, the damage done to the rectifier by an arc-back is negligible, particularly when protected by present high speed breakers. While a momentary outage is experienced the circuits may be reclosed after a few cycles. Graphite has proven to be the best anode material because it vaporizes directly without melting. In the event of an arc-back a very small quantity of material is vaporized and appears in the rectifier as carbon dust, whereas a much larger quantity of most other conducting materials would be melted.

Even with the greatest care in manufacture and with de-ionizing shields and grids, arc-backs still occur in a random manner, but in modern rectifiers the occurrence is so infrequent that they constitute a very minor annoyance.

One of the items of greatest interest when considering the installation of a conversion unit is its efficiency.

The losses in a rectifier unit as illustrated in Figure 10 occur in the transformer as iron and copper losses, in the rectifier as arc drop, and in the rectifier auxiliaries used to maintain a vacuum, to provide excitation, and to circulate the necessary cooling water. The transformer is a piece of equipment that has been manufactured for a great number of years and considerable work has been done to improve its efficiency. At the present time, transformers of the capacity used for ordinary industrial applications are up to the point where the losses are of the order of 2 per cent at full load, so there is not much left on which to work. The auxiliary losses constitute such a small percentage of the total loss of the installation that there would not be much gained if they were entirely eliminated. It so happens that approximately two-thirds of the entire loss of a conventional rectifier is dissipated as arc drop. Since is is known that the fundamental arc drop of a simple mercury vapor arc is less than 10 volts, it is only logical that engineers should give considerable atten-

FIGURE 12—A commercial Ignitron tube with a d-c. current rating of 500 amperes.



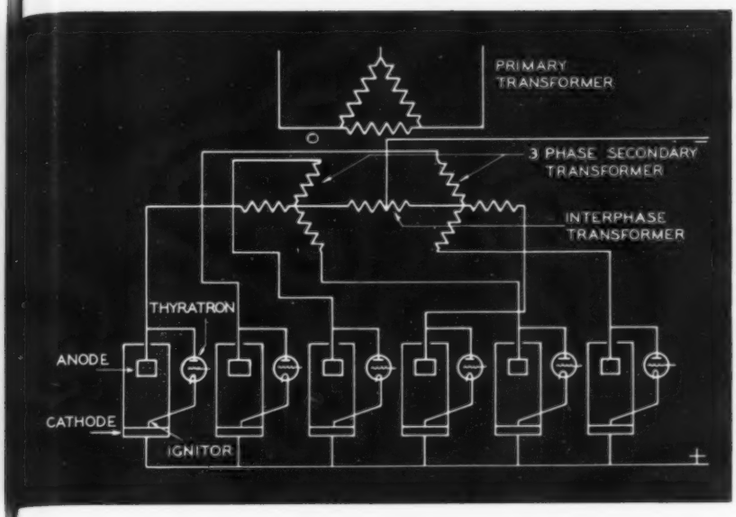


FIGURE 13—Typical six-phase rectifier circuit, using two three-phase transformers and Ignitrons.

tion to this particular point with the view of developing a design that would reduce these losses. The arc volt drop of a particular design is practically constant, there being but a few volts difference between that obtained at light loads and full load. This produces a relatively flat efficiency curve. In a rectifier tank with a large number of anodes, the arc drop becomes greater due to the necessity of wider spacing between cathode and anodes and the addition of the larger de-ionizing grids and baffles.

In the interest of obtaining a more efficient unit and also a more simplified design with consequent greater reliability, we have developed what is known as the Ignitron rectifier, which provides a separate tank for each anode, and utilizes synchronous ignition instead of continuous excitation. Such a design is illustrated by Figure 11.

IGNITRONS

If a rectifier can be built so that there is no arc in the vacuum chamber during the period of the cycle when the anode is bearing back voltage, a great deal of the tendency to arc back is avoided. This has been done by use of the Ignitron principle of starting the cathode spot only when the arc is required for forward transport of current and allowing it to die out when the anode current becomes zero.

Dr. Slepian found that if a current is passed through a substance of relatively high resistance, which is immersed in a substance of good conductivity, a gradient will be established at the junction between the two substances that is high enough at a given current to ignite a cathode spot. By the use of the correct materials this current is of the order of 15 amperes which is a very reasonable value for power applications. The ignition of an arc in this manner is accomplished in a very short time, only a few microseconds. It is done synchronously, in somewhat the same manner as the ignition of an automobile engine is timed through the distributor to synchronously fire the cylinders with the rotation of the crankshaft. The Ignitron is constructed around this principle and since the arc can be started each cycle, the anodes are placed in individual tanks and the arc is permitted to go out at the end of each conducting period. Therefore, during nearly all of the period when the anode is negative, there is no ionization or other disturbances in the space, and all direct effects of the arc on the arc-back hazard are removed, leaving only those due to certain residual effects.

Thus, in an Ignitron, the anode is placed quite close to the mercury pool, and the degree of shielding materially reduced from that used in a conventional rectifier. The result is that increased efficiency is obtained without a reduction in reliability. This is particularly attractive at 250 volts where the arc drop volts are a larger percentage of the output voltage.

Since the Ignitron is built in single anode tanks, the number of anodes, required by the particular rectifier circuit being used, are obtained by assembling the necessary number of Ignitron tubes into a unit. Figure 12 shows commercial Ignitron tube which has a d-c. current rating of 500 amperes.

IGNITRON CIRCUITS

Figure 13 is a diagram of a typical Ignitron rectifier circuit. This differs from the conventional rectifier circuit only in that the usual arc striking and excitation means are omitted and small thermionic cathode tubes or thyratrons, for the control of the make alive current impulses in the ignitors have been added.

Obviously, the power required for control of thyratron grids is much less than that required for conventional rectifier grids and the control apparatus is correspondingly smaller.

The same fundamental type of construction is used in the manufacture of metal tube Ignitrons as is used for conventional rectifiers, that is, they are made of welded sheet steel, vacuum tight insulating bushings, vacuum gaskets, etc. The larger sized tubes are designed to be continuously pumped and in application are connected to conventional vacuum pumping system through a vacuum manifold. The tubes may be assembled in any number to suit the requirements of the circuit and the convenience of the mechanical arrangement. Practically, the assembly of more than 12 tubes on one vacuum system presents some difficulties and it is probable that assembly in units of six will be found most attractive for the majority of applications. Figure 14 shows a six tube unit having a rating of 750 kw. at 250 volts or 1500 kw. at 600 volts.

Metal tank Ignitrons must be cooled with water, the same as metal tank conventional rectifiers. Because of the relatively small size of Ignitrons they are made of stainless steel, and are cooled by soldered, or welded on copper coils through which the cooling water is passed directly. This provides a completely non-corrosive unit.

Typical efficiency curves of 750 kw. Ignitron units at 600 and 250 volts are compared to those of conventional rectifier, synchronous converter and motor-generator sets in Figure 15. The influence of the lower arc drop of the Ignitron rectifier is evident, and this

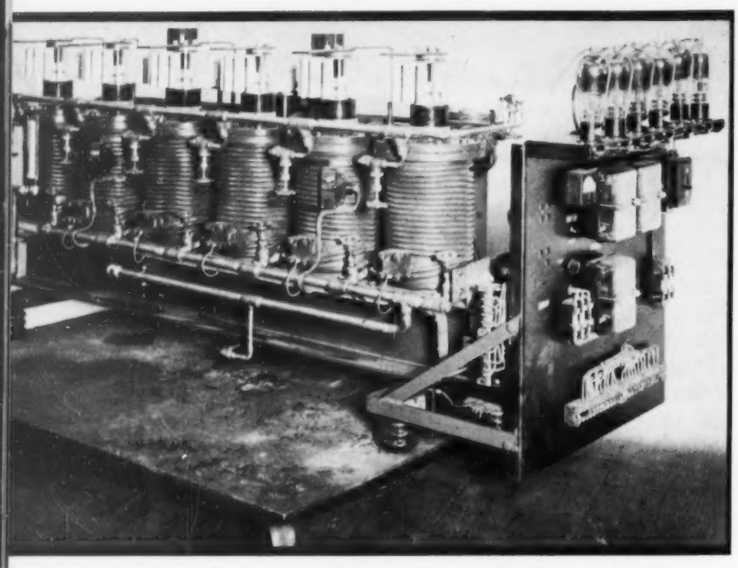


FIGURE 14—Six tube Ignitron unit having a rating of 750 kw. at 25 volts, or 1500 kw. at 600 volts.

improved efficiency has greatly increased the attractiveness of arc rectification for 250 volt service.

Even a conventional rectifier has a distinct advantage over a motor-generator set at full load at 600 volts. This no doubt partially accounts for its application in the railway field and on 600 volt electro-chemical installations. In the steel industry 600 volt applications are usually variable voltage of one type or another where regenerative braking is desired. As yet rectifiers are not well suited for such applications.

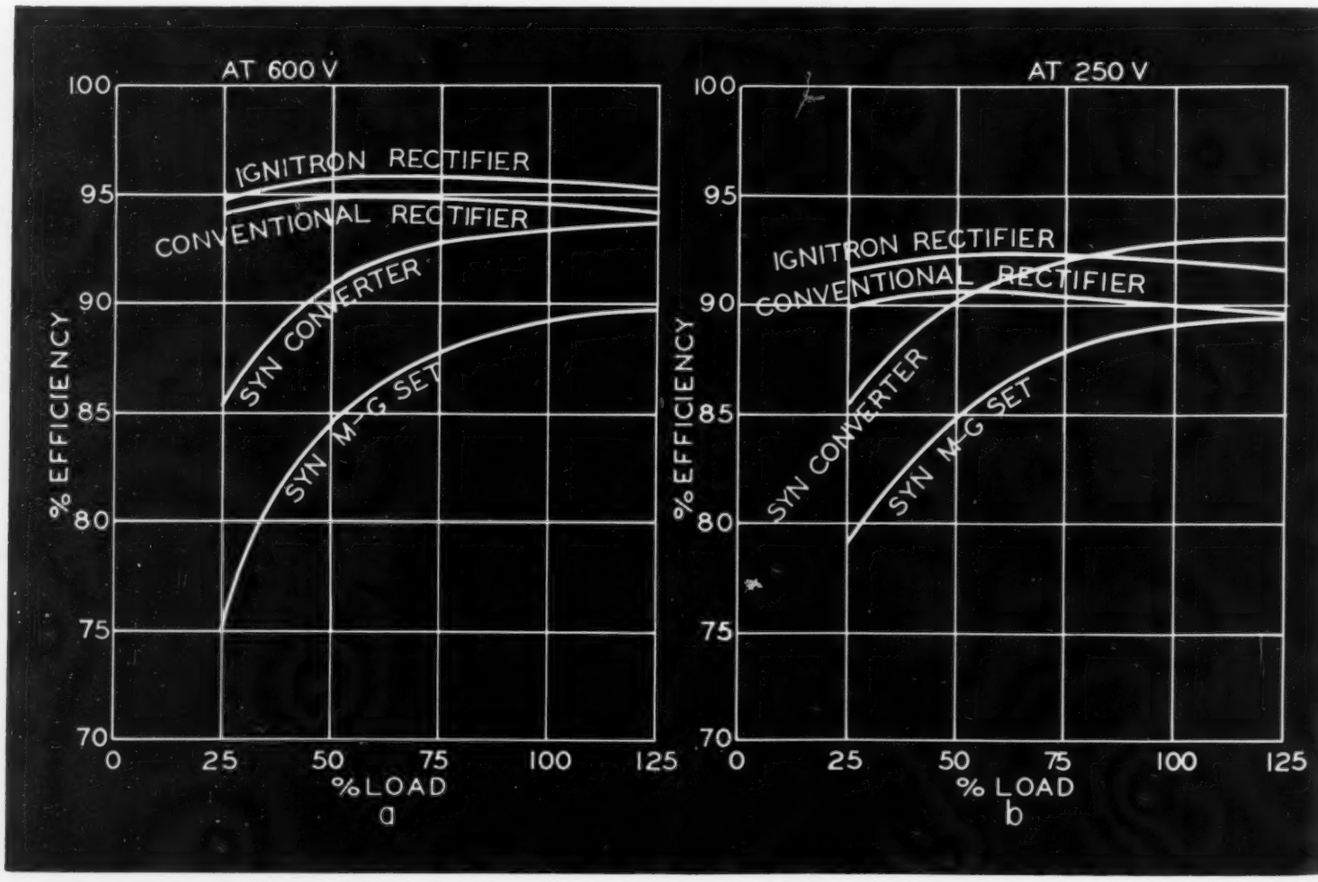
In the steel industry, the problem of supplying 250 volts is usually one of simple conversion. The conventional rectifier has a distinct advantage only at light loads, with little margin at full load. The Ignitron rectifier has three times the margin at full load that the conventional rectifier has, and retains a margin over the motor generator set and conventional rectifier at light loads.

IGNITRON APPLICATION

Ignitrons have already been applied rather extensively. The larger, pumped, units are in service in the mining and electro-chemical industries and applications are being made in the electric railway industry.

Figure 16 shows a recent Ignitron installation for an electro-chemical company. The equivalent includes six assemblies of six Ignitron tubes each and is rated at 4800 amperes for 285 volt operation. These units are used with indoor transformers for the production of

FIGURE 15—Comparison of typical efficiency curves from 750 kw. capacity conversion apparatus.



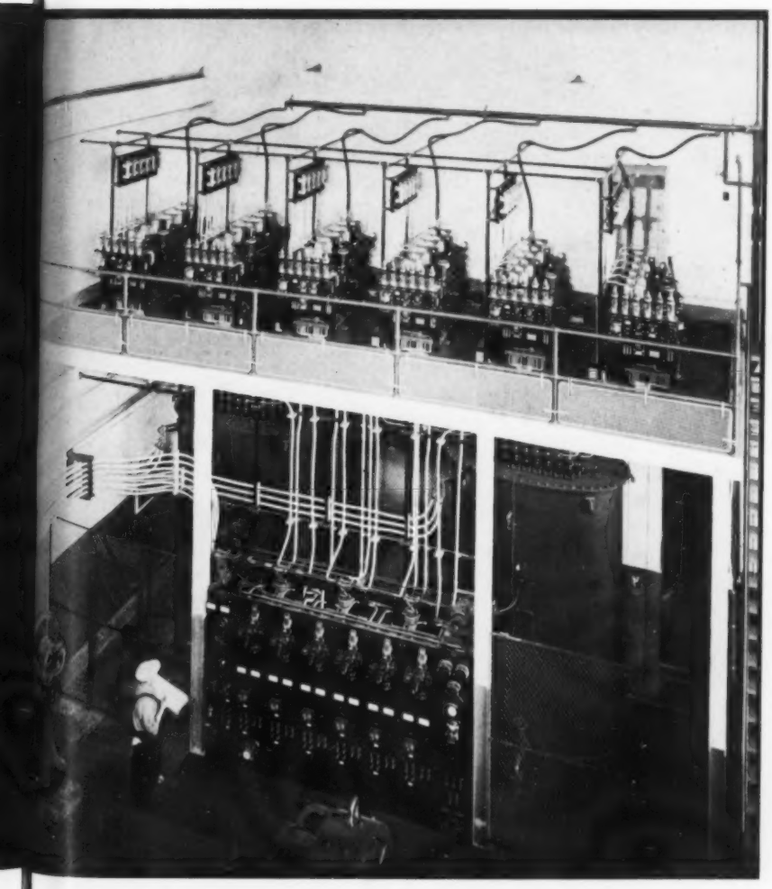
hydrogen peroxide and are controlled manually from the switchboard.

Since any function performed by a conventional rectifier can be performed by an Ignitron, at voltages up to 600 at the present time, with considerably less loss, and with greater flexibility, there seems little question but that as the Ignitron by actual service builds up a reputation for reliability, it will gradually obsolete the conventional rectifier. It is also probable that if applications are desired, the Ignitron will be developed for higher voltages than 600, since there is no evident barrier to higher voltage design.

CONCLUSIONS

The present day success of many of our most complicated and difficult steel mill applications have only been possible with the use of variable voltage equipment utilizing motor-generator sets. The field of the generator of the motor-generator set can be increased, held constant, regulated or decreased at will, and at various rates, depending upon the requirements. The field may be forced to obtain rapid acceleration of the driven equipment, or its rate of decay can be regulated to obtain regenerative braking.

FIGURE 16—This installation includes six assemblies of six tubes each, and is rated at 4800 amperes for 285 volt operation.



The performance of a reversing mill, a continuous hot or cold mill, a flying shear as well as other exacting applications would not be possible if we could not utilize the flexibility of the field of a d-c. generator.

The ultimate of these applications was only obtained after years of experience, and in time we may expect the rectifier to be substituted for the motor-generator set on some of these difficult installations. It, however, seems logical that the first experience in this industry should be obtained on 600 or 250 volt constant voltage power systems.

Where the duty is one of simple conversion, improved efficiency of the Ignitron rectifier should make it perticularly attractive. In addition to this there are other influences that now make the mercury arc rectifier of more interest than in the past.

In recent years so much synchronous capacity has been installed in steel plants that power factor correction as obtained from a synchronous motor-generator set is not the factor that it was several years ago. For this reason the fact that the mercury arc rectifier operates at a slightly lagging power factor may prove to be an advantage in some cases rather than a detriment.

The power systems in steel plants are becoming quite large and the cost of switching equipment to rupture the large currents obtained on short-circuits is becoming a large item of expense. Synchronous motor-generator sets add to the value of the short-circuit current of a generating station or a substation. With a mercury arc rectifier there is no conversion of power from direct current to alternating current when the a-c. voltage drops, so the rectifier will make no contribution to the short-circuit current obtained.

Larger motor-generator sets and synchronous motors are being installed in steel plants so that the inrush of current is becoming more of an item, particularly if the size of the synchronous machine is relatively large on a smaller power system. Such an inrush is not obtained on rectifiers as they are merely connected to the a-c. circuit and the only inrush is the small exciting current for the transformer.

In the early period of electrification, we were not careful to provide clean air for rotating machines, but experience has taught us the value of protecting exposed windings from dirt. Today considerable money is spent to provide an expensive room for motor generator sets, as well as air cleaners and blowers to provide a clean supply of cool air. On a mercury arc rectifier installation the transformer can either be self-cooled or water-cooled, while the rectifier is water-cooled. This is a much simpler arrangement than providing air for motor generator sets, and will require less space and lower first cost.

Taking a broad view of everything involved, we believe the steel industry will find the rectifier well worth considering. There should be applications where this form of conversion will give the purchaser a greater return on his investment than that obtained from a motor-generator set or rotary converter.

DISCUSSION

PRESENTED BY

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W. E. GUTZWILLER, Engineer, Allis-Chalmers Manufacturing Company.
L. A. UMANSKY, Industrial Department, General Electric Company, Schenectady, New York.
A. L. LEE, Consulting Engineer, Pittsburgh, Pennsylvania.
L. A. WYND, Electrical Superintendent, Republic Steel Corporation, Chicago, Illinois.
G. W. BAUMGARTEN, Assistant Chief Engineer, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.
G. E. STOLTZ, Manager Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.
J. H. COX, Manager, Rectifier Engineering Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

W. A. PERRY: As the authors said, the electrical manufacturer anticipates in some cases, and in other cases the user of electrical power forces the electrical manufacturer into new fields. In this case it would seem that the electrical manufacturer is presenting to the steel industry a new device which in a short time no doubt many steel mills will be using. In fact at the present time some mills have them in stock.

F. W. CRAMER: In November, 1921, J. H. Milliken, consulting engineer, delivered a paper on the subject of "Mercury Arc Rectifiers" before the Pittsburgh Section of this Association. According to the records, this was the first paper on the subject to be given before an engineering body in this country. The paper was based entirely on European installations, for according to the author, there were no commercial installations in this country at that time. However, credit for the origination of rectifiers was given to Peter Cooper-Hewitt, an American who discovered the phenomena of the valve action of the mercury arc in a vacuum which permits the flow of electric current in only one direction.

In the discussion of this paper, B. G. Lamme told of the work done to develop a mercury arc rectifier. The chief topic of Mr. Lamme's discussion was that although manufacturers had at that time (1921) developed commercial rectifiers, they were unable to locate a market for them, the customers preferring either motor generator sets or rotary converters. He believed, however, that there was a field for rectifiers in the electro-chemical industries, and the electric railways. From published lists of present installations, these predictions have been proven correct.

I have been told that at the present time there are over 2,500,000 kw. of rectifiers installed throughout the world, of which about 700,000 kw. are in the United States; but of these 700,000 kw., only 1,000 kw. or 1 unit is installed in the steel industry of this country.

This condition naturally raises the question, "Why has the steel industry not adopted rectifiers as the source of d-c. power?"

The paper this morning is one of the best non-mathematical presentations of the theory of rectifiers that has been presented to the engineers of the steel industry. The apparatus described has proven the claims made for it in actual service in other industries, but no specific recommendations are made as to the types of applications for which the apparatus is especially suited in our industry.

It is apparent that steel mill electrical engineers are skeptical of the operating reliability and economics of rectifiers. In order that the authors of this paper as well as other manufacturers of rectifiers present at this meeting may have the opportunity of answering some of these objections, the following questions have been compiled:

1. The paper states that the delivered cost of a rectifier unit is about the same as the comparable motor-generator set. What we are interested in knowing is the completed or ready-to-run investment costs of the two systems, including foundations, ventilating equipment, buildings, etc., under the following conditions:
   (A) As a source of general d-c. mill supply:
      1. In manually operated substations, both attended and unattended.
      2. For automatic substations.
   (B) As a source of d-c. supply for main drives, for single stands of unidirectional merchant mills, or reversing mills where variable voltages are not required.
   (C) As a source of d-c. supply for ore bridges or coal bridges.

   If a lower total investment cost can be shown on any or all of these types of installations, a point in favor of rectifiers will be established.
2. What is the influence of a monthly load factor of 80 per cent, and of 40 per cent, on relative overall efficiency and losses in the two types of equipment of 1,000 kw. size, if power costs are 1c. per kwh.?
3. What degree of variation do rectifiers permit in voltages by means of grid control, and what are the limitations of the equipment when used in applications requiring variation of voltage?
4. How large an installation can be made before interference with telephone communication or radio reception is experienced, due to the distorted current waves?
5. Many steel mills generate 25-cycle power and purchase 60-cycle power. In case both sources of power are 6600 volts, what is the additional cost for a 1,000 kw. 60-cycle unit that can also be used on the 25-cycle system?
6. The authors call attention to the fact that mercury arc rectifiers do not contribute to the short circuit

currents in a power system. Since the average transient reactance of a synchronous motor is about 20 per cent, an installation of 10,000 kw. in motor generator sets would contribute a possible 50,000 kva. to the rupturing capacity of the circuit breakers required by a system. Have any installations been studied, whereby the installation of rectifiers instead of motor generator sets would result in smaller oil circuit breakers being required?

7. What do the existing installations of rectifiers show on maintenance? Motor inspectors are not familiar with vacuum pumps and other accessories necessary to this equipment, and would probably be at a loss on what to do in case trouble develops.
8. How does a rectifier compare with a motor generator set, as regards continuity of service and reliability of operation?
9. Due to the requirements for circulating water for cooling purposes, do rectifiers have to be installed in heated rooms to prevent freezing in winter weather?

As pointed out in the paper, power factor correction in present day steel plants is not so important as when Scherbius sets and wound rotor motors were the predominant main drives. The design of motor generator sets has about reached the limit regarding efficiencies and performance, and on certain installations, the d-c. power requirements demand a very complicated system of control and auxiliaries for the operation of the sets. The design of mercury arc rectifiers, with the existing arc drop of 16 volts has not reached the limit of possible efficiency or performance, and it offers a simple control system. The cost of rectifier units should decrease as development costs are absorbed, and their manufacturing processes standardized.

The steel mill operators must be convinced that, in addition to having a better efficiency than motor generator sets, rectifiers also have:

1. Equal or better maintenance costs.
2. Equal or better records for continuity of service.
3. Lower investment costs for the complete, "ready-to-run" installations.

If the above conditions can be satisfied, there should be a field for rectifier installations in the steel industry.

W. E. GUTZWILLER: I want to emphasize the statement made in the paper: "This development has reached a stage where the steel industry should now consider its installation". Today we no longer have to point only to experience with rectifier installations in other industries, but are fortunate to have actual operating records on a typical rectifier unit which has, for nearly two years, supplied all general purpose power to a steel mill. We have among us today operating men who have largely been responsible for this pioneer installation in the steel industry. I hope they will be able to give us their experience and operating data gained with this unit. This is what the operating people want to know above all, and I am sure will convince you that the rectifier is fit for steel mill service.

The paper of Messrs. Stoltz and Cox brings out that for main roll drives and other variable voltage applications where voltages of 500 volts and higher are employed, the rectifier does not quite have the operating flexibility of a motor-generator. This deficiency is, however, offset by the higher efficiency, low starting current, greater stability under a-c. system disturbances, lower installation, operating and maintenance cost. The first costs of rectifiers at 500 volts and higher compare favorably with those of motor-generators. For 250 volt mill supply where, as a rule, constant voltage is required, the relatively high first cost and low efficiency of the mercury arc rectifier has so far been a draw-back to its application. The cost of rectifier equipment at this voltage is approximately 20 per cent higher than that of motor-generator sets. However, there is sufficient saving in the installation cost of rectifiers to make the overall installed cost about equal to that of the motor-generator.

There is no question but that the single-anode rectifier referred to in this paper is a step forward in the application of rectifiers to industrial plants. The single-anode rectifier is more flexible in operation. Its overall conversion efficiency at 250 volts is from 2 to 3 per cent higher than the multi-anode rectifier, and ½ to 1 per cent higher at voltages of 500 to 600 volts. The problem of cooling and temperature control of the smaller single-anode rectifier is bound to be simpler. Furthermore, this type should also have certain manufacturing advantages over the multi-anode tank.

Unfortunately, with the rectifier, as with any other type of equipment, a major improvement in one direction is usually obtained by sacrifices in other directions. The disadvantages at the present time are greater complications of auxiliary and control devices, which are bound to increase the maintenance cost. It is hoped that as time goes on, and experience is being gained, some of these disadvantages which today seem to partly offset the gain in efficiency and flexibility will be overcome.

This is not the place to get into arguments as to whether the single anode or the multi-anode rectifier is to be applied. Steel mill engineers are not so much interested as to what is inside of these tanks and how they operate as long as the rectifiers perform the service for which they are intended, and do it more economically than older types of converting apparatus. Manufacturers can offer you today the multi-anode as well as the single-anode rectifier tanks, each of which has its place in the steel industry.

L. A. UMANSKY: It must be apparent to the steel mill engineers that the electrical manufacturers are ready to produce workable and reliable rectifiers for d-c. supply. It is true that we are not yet ready to concede that the rectifiers are well suited for such applications where the d-c. voltage should be frequently and rapidly changed, and where power regenerative braking is vital. I refer, for instance, to the Ward Leonard circuits as used for reversing blooming mills, for tandem and reversing cold strip mills, and like. With these exceptions there is really no valid, purely engineering reasons why rectifiers should not be used for 250 volt mill supply, or for furnishing 600 volt power to merchant, rod, and even hot strip mills, instead of the presently accepted motor-generator sets.

No one can claim that the control of the rectifier is better or simpler than that of the motor-generator

set. It is either as good or is almost as good. But, there is no point in replacing an old tool with a new one unless the new tool works better with the same expense, or works equally well at a lower cost. It is on this ground that the rectifiers should prove their worth.

And what are the facts in the case? Unfortunately, the first cost of rectifiers, in this country at least, is still higher than that of motor-generator equipments, which is particularly true at 250 volts. You must remember that the total cost of rectifier equipment is composed of three parts: Transformer, rectifier proper, and switchgear or control. The cost of transformer is, roughly speaking, proportional to kw rating. The cost of rectifier is proportional to the ampere rating; hence, we have a higher cost per kw of rectifier equipment at 250 volts than at 600 volts, while with the motor generator sets this difference, if any, is slight. This extra first cost of 250 volt rectifiers can not be always or completely offset by the possible lower cost of installation. There remains the higher efficiency of the rectifier, particularly at light loads. If this reduction of conversion losses can be capitalized to offset the higher first cost, then the rectifiers have, figuratively speaking, a leg to stand on.

The introduction of the igniter gives the rectifiers a definite advantage. The efficiency is higher than that of the multi-anode tank, particularly at 250 volts. This factor is bound to strengthen the relative position of rectifiers. We recognize this fact and are actively developing the single-anode rectifiers, both for 250 volt and 600 volt service. The 3000 kw., 600 volt, i. e., 5000 ampere, unit built for the N. Y. Board of Transportation, well illustrates the progress made in this line.

Why, we may well ask, was the steel industry somewhat more reluctant to apply rectifiers than were the transportation or electrochemical industries? In the latter fields the rectifiers serve as a purely power converting apparatus, eliminating the rotating machinery altogether from the sub-station. The whole aspect of the substation is changed; it becomes unattended. On the other hand, in a mill motor room such rotating machinery as the mill motors themselves will obviously remain, and the addition of one, or several motor-generator sets will not change the situation materially. The 250 volt general purpose mill supply service has more similarity in this respect with the railway service; but in the latter 600 volts or higher voltages are used and the rectifier all-day efficiency and first cost show up better.

In European steel mills the use of rectifiers is much wider than here. I remember having seen, as early as in 1927, several plants in Belgium and northern France with rectifiers providing all d-c. power for auxiliary and main drives—except for reversing mills. But, the d-c. systems were 500 volts instead of 250 volts. In Russia many rectifiers were recently installed for 250 volt steel mill service—for the simple reason that the available manufacturing facilities permitted faster production of rectifiers than of motor-generator sets; the growing steel industry was clamoring for converting apparatus, regardless of first cost or even efficiency.

I am very curious to know whether the majority of steel mill engineers are prepared to change their customary attitude of preferring something well established and workable in favor of a new apparatus on the sole basis of a somewhat better efficiency. I am thinking, for instance, of another well known and now rather reliable converting equipment like synchronous converters, which invariably have higher efficiency than the motor-generator sets. The first cost is usually lower. Several steel mills get excellent results with rotary converters. And yet, you are purchasing very few converters. Will you do likewise with rectifiers?

Our views on suitability of rectifiers for this or that particular application in steel industry is clearly stated in the August issue of "Iron and Steel Engineer"—in the paper presented by Messrs. Snyder and Herskind.

I want to second the speaker's invitation to you to consider the use of rectifiers whenever you have a power conversion problem. But I will add: Do not use the rectifiers just because they are a novelty; let them prove their dollar's worth in each case by a hard-boiled dollar test.

A. L. Lee: During the last few years we have experienced a rather phenomenal growth in the field of application of electronics. It should not seem strange, therefore, to find that this influence is extending more and more certainly into the fields of large power conversion, and the control of various functions of industrial electrical equipment.

Experience during recent years indicates that the modern mercury arc rectifier offers new possibilities particularly with respect to the efficiency of power conversion. Improvements in construction, reduction of arc losses, and the development of grid and ignition methods for excitation and voltage control have been such that serious consideration of the rectifier is now justified for the large majority of applications requiring the conversion of a-c. voltage to d-c.

The most notable advance has been the development of the ignition type rectifier which has further enhanced the economic advantages of the rectifiers and made possible its advent into the field of the lower d-c. output voltages. It is, of course, still quite true that in order for new equipment and methods to extensively displace existing and proven ones, superiority must be quite apparent with regard to operating advantages, cost, efficiency, and maintenance as they may be collectively viewed.

As the speaker is more closely associated with the coal mining industry, a rather general comparison of the power applications of underground mining with those of a steel mill may be of interest. While to a very large extent underground mining equipment must operate at variable speeds, those units are largely mobile and are generally served by an extensive direct current system of desirably constant voltage with speed control by means of armature circuit resistance applying to the individual unit.

The problem of maintaining constant voltage in a large mine is a very serious one and has in many cases resulted in the establishment of networks of trolley and feed circuits with conversion units located so as to best serve the various load centers.

Contrasted with the foregoing are the many large variable speed control applications of the steel mills where maximum efficiency and flexibility of control wage a constant battle. Parallel viewpoints for mine and steel mill requirements of the conversion unit no doubt exist with respect to the following characteristics:

Reliability
Efficiency
Instantaneous and overload capacity
Low cost of maintenance
A desirable power factor relation to the plant system, and in some cases voltage control, where parallel operation, compounding or possibly speed control of the driven unit is required.

The possible advantages of the rectifier with regard to these points have been well reviewed in the paper under discussion. A number of 250 volt ignition type rectifiers have been installed in coal mines in the Pittsburgh district during the last one and one-half years, as well as several conventional tank type 600 volt units.

As the speaker is familiar with the selection and operation of the first of the ignition type units to be installed, a description and a summary of operation may be of interest. The equipment consists of a 300 kilowatt, 2300 volt, 3 phase, 60 cycle a-c. to 275 volt d-c. ignitron rectifier and associated equipment. The equipment, other than the rectifier proper, consists of the following:

The main 3 phase to 6 phase power transformer Inerteen cooled for fire and explosion protection. (I might say here that this rectifier is installed approximately two and a half miles underground and had to meet very rigid requirements of the State Mining Department.)

Complete automatic and protective switch gear.

The rectifier cooler consisting of a water to air heat exchanger with pump, fan, and piping.

Incoming line disconnecting equipment.

Voltage compensation and compounding are accomplished in this equipment by means of automatic control of the grid voltage of the thyratron ignition tube and is accomplished without moving parts. This feature is essential for most mining operations to provide for proper parallel operation and load division and to offset the effect of a-c. line voltage drop incident to a-c. power distribution.

To what extent the present means of voltage control of rectifiers may eventually be utilized in connection with steel mill control is problematical. As pointed out by Mr. Stoltz and Mr. Cox, a reasonable degree of voltage control is quite feasible with a double 3-phase rectifier circuit without excessive harmonic disadvantages and the possible effect of the uses of a number of rectifiers of either 6 or 12 phase design on a common supply circuit and with various degrees of voltage regulation is a problem for further investigation, as stated in the subject paper.

By and large, and probably through the establishment of custom and precedent, rectifiers have most commonly been arranged for a grounded negative installation. We are not convinced that this is to any great degree desirable as it entails the isolation and protection of the tank structure, thus requiring greater installation space and complicating the general arrangement.

Wherever possible, it is believed that the grounded cathode arrangement is more desirable and will provide a safer, simpler installation. Many arguments may be advanced regarding the effect of electrolysis arising from transportation circuits, but we believe that investigation will show that in the majority of cases, the effects will be less detrimental and less localized in nature with the latter arrangement. The mining unit just described is operating with the cathode or positive grounded.

Since the installation of this equipment, maintenance has been of minor consequence and the unit has demonstrated its ability to serve, without interruption, the widely varying requirements of mining service. Experience indicates that over a period of years maintenance and replacement costs should show an advantage for the rectifier.

In conclusion, it is believed that with careful engineering application, the mercury arc rectifier offers advantages well worth consideration in many fields of application where previously rotating equipment has dominated.

L. A. WYND: Opening remarks mentioned the trend toward a-c. applications. It is true that none of us here today would have a single direct current motor on our electrical systems if we knew how to dispense with them. Because we have not learned how to do this, we are still confronted with the necessity of generating large blocks of d-c. power. It is also true that efficiency is the factor upon which the most attention is focused as soon as we start comparing rectifiers with rotaries and motor-generator sets. Motor-generators have been practically standardized as steel mill conversion units, so we are most interested in using them as a basis for comparison.

Electric railway systems have been the greatest proving ground for rectifiers in United States. In that field the comparison must be made with rotaries. In Chicago there are 35,000 kw. in rectifiers on the Commonwealth Edison system supplying electric railways. 7,500 kw. of this is in 1,500 volt units for the electrified section of the Illinois Central Railroad. The balance is in 600 and 750 volt units for the elevated and surface lines. This company has recently standardized on 3,000 kw. size and has units manufactured by three different companies in its substations, the first installation being placed in service in 1926. The trend in this system is very definitely toward rectifiers.

Just last week I learned of a rectifier installation on the Edison system that had some new features, so arrangements were made to see it. This is a 3,000 kw. unit located in the Ardmore substation on the north side of Chicago, supplying elevated lines in its vicinity. The new features of this installation are the multiple tank and the vacuum sealing arrangement.

Printing firms seem to be leaning toward rectifiers, Chicago having two companies using this method of obtaining direct current. These installations were also visited recently. The first installation of this kind was made at the Alco Gravure Company plant at Western Avenue and 15th. Place in November

1935. That company has two, 200 kw., 250 volt rectifiers, arranged for automatic paralleling when load conditions require it. They are the only source of d-c. for the elevators, presses and all other drives in the building. The second installation is located at the Radio Guide Publishing Company, 731 South Plymouth Court. It consists of two 400 kw., 250 volt units arranged similar to the earlier one. They were placed in operation in November 1936. This company does not regularly employ an electrician, depending upon a nearby contractor when in need of service. The rectifiers at both printing firms operate without regular attendants. Both places report excellent results and no failures.

In the electro chemical industry, rectifiers are very rapidly replacing other means of direct current conversion. A single order for rectifiers from one such company in 1937 totalled over 83,000 kw. and cost one and three-quarter millions of dollars. 750 tons of steel products were used by the manufacturer in building these units.

Before the Republic Steel Corporation decided to install the 1,000 kw., 250 volt rectifier, now operating in the new wire mill at South Chicago, several inspection trips were made to railway substations where rectifiers and rotaries were both operating. During these trips, early in 1936, a number of operators and supervisors were contacted. These men were all very frank in discussing troubles and said that considerable grief had been experienced with the first units, but that the development of heat exchangers and high speed breakers had eliminated the serious problems. The consensus of opinion of this group favored rectifiers for dependability, low maintenance, and rapid restoring features in case of outage.

Following the inspection trips, the efficiency angle, as related to probable load factor was carefully considered. It was decided that these units had reached a point in their development where they are as dependable as motor-generators and have some advantages the older units do not have. Total cost of the rectifier installed ready to operate did not appear to be much different from that of a motor-generator set, and there was an excellent chance of saving considerable money on efficiency and maintenance. The balance of opinion favored the rectifier.

Final installation costs were 5 per cent lower than estimated equivalent motor-generator. Due to the necessity for building a transformer vault, to comply with city electrical and building codes, installation costs were not as low as can be realized in some localities. Installation in most cases should run at least 10 per cent lower than motor-generator costs. This is due to lighter foundations, no leveling, no grouting, easier movements of the units from railway cars to location, and no provision for air filtering. Electrical work will be slightly less.

By September 1st., this year, the rectifier at South Chicago had operated 12,500 hours. Input 2,216,500 kwh. Output 1,950,000 kwh. Load factor 15.6 per cent. Efficiency 88 per cent. The same size motor-generator set under identical load conditions will have 73 per cent efficiency. Efficiency savings amount to $3,369. This amount is about $500 greater than would have been earned with the normal purchased kwh. cost under full operations. The following maintenance costs include all money spent on the rectifier since it was placed in service.

72 hours of labor at $1.10	$ 79.20
Cooling water	154.00
Oil for low vacuum pump	3.80
Total all maintenance	$237.00

A breakdown of the labor shows the following:

18 hours adding water to the closed cooling circuit.
12 hours cleaning high vacuum pump water jacket.
9 hours adding and changing oil on low vacuum pump.
2 hours cleaning low vacuum pump motor bearings.
2 hours cleaning circulating water pump motor bearings.
2 hours repairing water float gauge.
8 hours changing low vacuum pump. (This was done because the rectifier manufacturer thought we should have the benefit of an improved design. No trouble was experienced with the original pump.)

The net savings amounted to $3,132 for 521 days of operation, or $6.00 per day.

Operation of the unit has been very satisfactory. No arc-backs have occurred. During the second year of operation one service interruption of ten minutes occurred. This was caused by accidental pressure drop in the mill water supply which tripped the water failure relay. A repetition of that incident is not likely to happen.

This description is not complete without briefly mentioning load conditions the rectifier has to meet. Present connected load totals 1,176 horsepower or 880 kw. and consists of the following current consuming equipment: One ten ton and two five ton steel mill type cranes, three sixty inch lifting magnets eleven continuous wire drawing machines using a total of 31 adjustable speed motors, adjustable speed motors on annealing and galvanizing take-up frames, and all excitation on the synchronous motors and plating generators in the electro-galvanizing department. Load factor on the rectifier is frequently 50 per cent for eight hours. Occasionally it reaches 70 per cent for a few minutes. Over week ends and periods of reduced operations with only a few pieces of equipment operating it is about 10 per cent. Occasionally it is down completely for 24 hours.

Two departments using rectifier current require constant voltage for their most successful operation. The motor speeds on the continuous wire drawing machines and the take-up reels on the electro-galvanizing frames must be maintained very closely to their respective field settings. The fields of the plating generators must be maintained very closely so weight of coating will be uniform. Automatic grid control has been very successful in meeting the exacting conditions on these circuits. Control builders, during inspections of their equipment, have commented on the excellent voltage conditions prevailing on the d-c. system. For complete details of the Republic Steel Corp. installation at South Chicago, you are referred to the May 1937 and June 1938 issues of the IRON AND STEEL ENGINEER.

At this point I want to suggest that the rectifier manufacturers be in a position to furnish non-inflammable transformers with their rectifiers, which will lower installation costs in some localities.

In closing I want to compliment the authors upon the success of their company's research into the important and difficult problem of reducing arc drop.

G. W. BAUMGARTEN: I gathered the fundamental difference between the rectifier that was spoken of was the method of timing the Ignitron, in that it was timed for the instant that it was needed and then turned off, so to speak, when not needed. I also gathered that that function was in this thyratron tube, which was used, but we were not told in simple language very much about that tube or how it functioned.

G. E. STOLTZ: I think this discussion has proved to be more valuable than the original paper.

I will attempt to answer some of the questions raised by Mr. Cramer.

One is, why the steel industry has not adopted rectifiers previously.

I think there are very logical and definite reasons why rectifiers have been used in other industries earlier than in the steel industry. The steel industry has not been backward, but has used very good judgment in deferring the installation of this type of equipment.

Most of the 600 volt applications are variable voltage on which we have had little or no experience with rectifiers.

Commutators, as they exist today, perform very well, and there has been no urge to get away from commutating machines.

Where the problem is one of simple conversion it is practice to use 250 volts. Until the Ignitron rectifier was introduced this type of conversion was not attractive for this low voltage.

The cost of an interruption in the steel industry is greater than in many other industries. If one unit fails it may shut down a whole series of operations and prove to be quite expensive. For this reason the steel industry must be conservative.

To answer Mr. Cramer's question as to the type of application on which the rectifier should be used, we believe the first installations should be for simple conversion of any d-c. voltage as low as 250.

The next question raised by Mr. Cramer, and a very good one, is the relative installed cost of rectifiers as compared to motor generators. Of course, this will vary widely with individual applications. In Mr. Wynd's discussion he mentions that he was required to provide a transformer vault, while ordinarily an outdoor transformer can be used. He reports the installed cost of 1000 kw. rectifier for 250 volts will be about 5 or 10 per cent less than for the motor generator set in spite of the fact that the price of the rectifier itself is higher. This should apply whether the station is automatic or non-automatic. The character of the load, other than its value of voltage will have no particular influence on the cost of the installation.

To determine the relative overall efficiency of an Ignitron rectifier and a motor generator set of 1000 kw. capacity for a month it would be necessary to integrate the varying losses, but an approximation can be determined by using the efficiency at the load factors selected. Mr. Cramer has suggested load factors of 40 per cent and 80 percent with power costing 1c. per kwh. Using the efficiencies from Figure 16 the following results are obtained on the basis of 500 hours operation per month.

CALCULATIONS FOR 250 VOLT:

(1) 80% load factor			
Average kw. input of m.g. set	800 ÷ .88	=	909
Average kw. input of Ignitron rectifier	800 ÷ .92	=	870
Kw. saving	909 — 870	=	39
Kwh. saving per month	39 x 500	=	19,500
Dollars saving per month	19,500 x .01	=	$195
(2) 40% load factor			
Average kw. input of m.g. set	400 ÷ .84	=	477
Average kw. input of Ignitron	400 ÷ .92	=	435
Kw. saving	477 — 435	=	42
Kwh. saving per month	42 x 500	=	21,000
Dollars saving per month	21,000 x .01	=	$210

CALCULATIONS FOR 600 VOLT:

(1) 80% load factor			
Average kw. input of m.g. set	800 ÷ .88	=	909
Average kw. input of Ignitron	800 ÷ .96	=	834
Kw. saving	909 — 834	=	75
Kwh. saving per month	75 x 500	=	37,500
Dollars saving per month	37,500 x .01	=	$375
(2) 40% load factor			
Average kw. input of m.g. set	400 ÷ .84	=	477
Average kw. input of Ignitron	400 ÷ .96	=	417
Kw. saving	477 — 417	=	60
Kwh. saving per month	60 x 500	=	30,000
Dollars saving per month	30,000 x .01	=	$300

At 600 volts the saving is not as great at low load factors as at large, but at 250 volts the Ignitron efficiency curve is lowered so that the margin at large loads is not so great and the saving at low average loads is greater than at the higher average loads.

With grid control the voltage of a rectifier can be varied from zero to full voltage. The power factor decreases in proportion to the voltage. The chief limitation is the complication and cost to provide regenerative braking or constantly reversing service for variable voltage applications.

The next question is the cost of using a 60 cycle rectifier for 25 cycle. It is necessary to purchase a 25 cycle transformer which of course costs more than a 60 cycle transformer. The 25 cycle transformer will be designed to have the proper reactance on 60 cycle, and an additional reactor will be needed to provide the necessary reactance for 25 cycle. This would involve an added cost of $1000 for 1000 kw. capacity over that of the 25 cycle installation. Arrangement

must also be made to operate the auxiliaries and controls when the change is made.

Mr. Cramer asked the measure of reduction in the rupturing capacity of oil breakers obtained by the use of rectifiers instead of motor generator sets. In general our steel plants require from 500,000 to 250,000 kva. short-circuit capacity. 50,000 kva. would represent a reduction of 10 per cent in the former case and 20 per cent in the latter.

Messrs. Wynd and Lee have given concrete figures as to maintenance and reliability of rectifiers. It is of particular interest that printing companies should operate rectifiers without an attendant but depend on local contractors.

There is no greater need for a heated room for circulating water than for other systems now in common use.

Mr. Umansky raised the question of why the steel industry does not use rotary converters. Years ago rotary converters were not as stable as motor generator sets and the voltage from a rotary is influenced by the a-c. voltage. With better a-c. voltage regulation today this is not so important as formerly. There are a number of installations of rotary converters in steel plants, and the operators are very well satisfied.

J. H. Cox: Mr. Cramer asked regarding telephone interference. The amount of this interference The amount of this interference depends not only on the size of the installation but also on the length and proximity of the exposed communication lines. If objectionable noise is experienced it can be reduced to any desired value by the use of appropriate filters. In practice filters have been required only in a small percentage of cases and they have not been so large as to constitute an important percentage of cost.

Mr Wynd asked some questions regarding the latest Commonwealth Edison 3000 kw. rectifier at their Ardmore Station which is of the section type, consisting of four conventional tanks having six anodes each. The principal advantages of the multiple tank unit are, of course, its efficiency and flexibility. The arc drop goes up with the tank size and that accounts for about one percent in efficiency in a 3000 kilowatt unit at 600 volts. This amounts to about $5000 per year with an average load factor. The multiple tank unit has a flexibility and reliability that is not present in a single tank unit because if trouble is experienced it practically never involves more than one tank and you still have the remaining tanks available. Taking a four tank, 3000 kw. unit as an example, the three-quarters capacity that is always available permits the installation of a smaller capacity for a given load than would otherwise be needed.

The vacuum sealing arrangement consists of a process of soldering copper bands directly to the porcelain bushings, and the use of iron protected rubber gaskets for the larger flanges. Both these designs have proven entirely adequate for the service and are flexible in use. The vacuum pumping system is conventional except for an added barometric seal between the high and low vacuum pump that absolutely prevents atmosphere or oil from entering the tank in the event of a fault in the pumping system.

Mr. Wynd also asked regarding non-inflammable rectifier transformers. Of course transformers can be made non-inflammable by the use of Inerteen. As Mr. Lee pointed out, in our underground stations we have had to use non-inflammable apparatus.

Mr. Baumgarten asked about the timing circuit of Ignitrons and the thyratrons used in this circuit. The thyratron is gas-filled tube. This tube is used to control the impulses to the ignitors for starting the arc. It is a simple matter to apply synchronous impulses to the grids of these tubes to get the type of control desired. The power for the ignitor circuit may be taken from the main anode of the Ignitron or from a separate circuit. This seems to be a matter of taste and we chose Ignitron.

Mr. Reed has sent me some questions, "Will rectifiers operate in parallel with motor-generator sets and rotaries?"

"Will they operate parallel with one on 25 cycle system and the other on 60 cycle system?"

"Will there be any flow of power between the systems?"

Rectifiers will operate in parallel with rotating machines. All that is necessary is to provide similar regulation characteristics. If the rotating machine is compounded the paralleling would be more difficult, but it could still be done by the use of grid controlled rectifiers and some complication in control.

Again rectifiers on a 25 or 60 cycle will parallel with a rotating machine on the other system. However, the rectifier is different from the motor-generator set in that the a-c. voltage is reflected in d-c. voltage and the rectifier voltage output is proportional to the a-c. voltage. Thus, if the voltage fluctuates on the two different systems, it will cause corresponding fluctuation in the relative outputs of the rectifier and motor-generator set. However, we have several installations of that type, and there is no great amount of difficulty. Also, in one particular installation the 25 cycle system is not particularly constant. In this connection, high-speed control devices for a rectifier are available so it would not be difficult to obtain very high speed voltage changes.

A rectifier will not take reverse current unless special provisions are made, so there can be no power flow from motor-generator set to rectifier.

A rectifier can be made to take reverse current in which case it becomes an inverter, but the control is more complicated and the operation none too reliable.

That is the reason why rectifiers are not so attractive for many of the main mill drives, which demand regenerative power.

"Can you control the amount of power taken from each system?"

The amount of power taken from each system can be controlled by the control of the voltage outputs of rotating machine and rectifier.

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NEW *Irvin* WORKS *of* CARNEGIE-ILLINOIS FORMALLY OPENED

▲ WITH the formal opening, on December 15th, of all departments of the new Irvin Works, the Carnegie-Illinois Steel Corporation is in a position to supply hot or cold rolled strip or sheet, from 18″ to 77″ in width, in practically any desired finish, as well as tin plate and tin mill black plate. Ground was first broken for this new plant, which substantially expands the corporation's facilities in the Pittsburgh district, on May 22nd, 1937.

The new plant consists of an 80-inch continuous hot strip mill of the conventional modern design, complete with facilities for finishing hot rolled strip and sheet, a complete cold reduction tin plate mill, and a cold reduction strip and sheet mill, with the necessary pickling, annealing and finishing equipment. The cold reduction tin plate division of the plant was the first to be completed. Strip pickling, cold reduction equipment and all facilities for the production of tin plate were ready for operation in March, 1938, and pending completion of the remainder of the plant, coiled strip was shipped in from the McDonald 43″ hot strip mill, built by the corporation in 1935–1936 in the Youngstown district.

The size of this new plant can be appreciated when one considers that the site covers a total of 653 acres, which includes a river pumping station, reservoir, water treatment and sewage disposal plants, all plant wastes conducive to stream pollution being treated before discharge to the river. Over 13 miles of standard gauge railroad track within the plant is directly connected to the Union Railroad. The group of buildings in the mill itself has an overall length of 4275 ft., and an overall width of 1229 ft. The two largest individual buildings are the hot strip mill building, which is 94′ 9″ x 2424′ and the annealing building, which is 124′ 9″ wide by 2544 ft. long, both without any intervening cross partitions. Fifty-one and one-half acres are under roof in the 17 buildings which comprise the plant. Fifty overhead traveling cranes are installed, ranging in capacity from 5 tons to 60 tons with a 15-ton auxiliary.

Approximately 4,300,000 cubic yards of dirt and rock were moved in creating this man-made plateau 227 ft. above water level on the West bank of the Monongahela River, approximately 13 miles from Pittsburgh, demonstrating conclusively that the Pittsburgh area is by no means built up to its full capacity.

Electric power supply comes to this mill from the transmission lines at 66,000 volts, 60 cycles. The substation includes three 3-phase 69,000-6,900 volt transformer units each having a self-cooled capacity of 25,000 kva. and a forced air capacity of 33,333 kva. Large a-c. motors for the mill and the Monongahela River pumping station, as well as drives for auxiliary

W. A. Irvin, vice-chairman of the board, United States Steel Corporation, for whom the new plant was named, was greeted by B. F. Fairless, president of the same corporation, at the formal opening of the Irvin Works. Subsequently, Mr. Irvin received from J. F. Deasy, operating vice-president of the Pennsylvania Railroad, the telegraph key which Mr. Irvin used in his early life.

COURTESY PITTSBURGH SUN-TELEGRAPH AND I. N. S.

250 volt d-c. motor generator sets, are supplied directly from the 6600 volt distribution system. Medium and small size a-c. motors, lighting transformers and miscellaneous loads are served from 6,900-460 volt auxiliary transformers.

Slabs for the Irvin hot strip mill are shipped in over the Union Railroad from the Edgar Thomson Works, approximately 6 miles away. To assure a steady supply of slabs to the Irvin mill, the Edgar Thomson plant has been expanded by the installation of a modern 45″ x 80″ reversing-universal slab mill, capable of handling ingots up to 45,000 lbs. and rolling slabs up to 8″ x 60″ x 30 ft. long. Because of furnace limitations, the maximum length of slabs furnished to the Irvin plant is 18 ft.

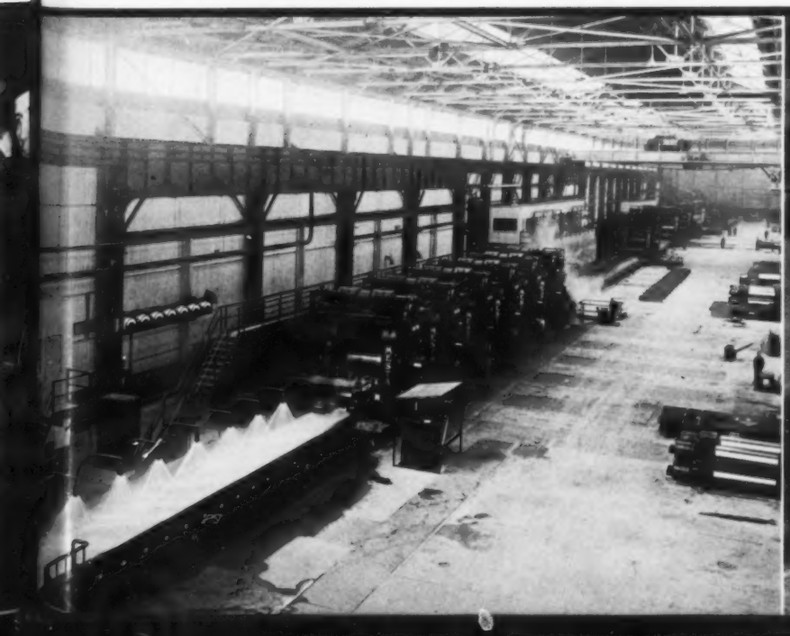
HOT MILL

These slabs are stored in the 64,000-ton slab yard at the north end of the Irvin Works, adjacent to the 80″ continuous hot strip mill. Slab conditioning beds with special facilities for removing surface imperfections by oxyacetylene scarfing are provided at each end of the slab yard. Three continuous zone controlled, triple fired slab heating furnaces utilizing coke oven gas are installed to assure an ample supply of hot slabs for rolling. Both ends of the furnace approach table are equipped with magazine feeders. Each furnace is equipped with two motor operated slab pushers. A slab return conveyor is installed at the end of the mill approach table.

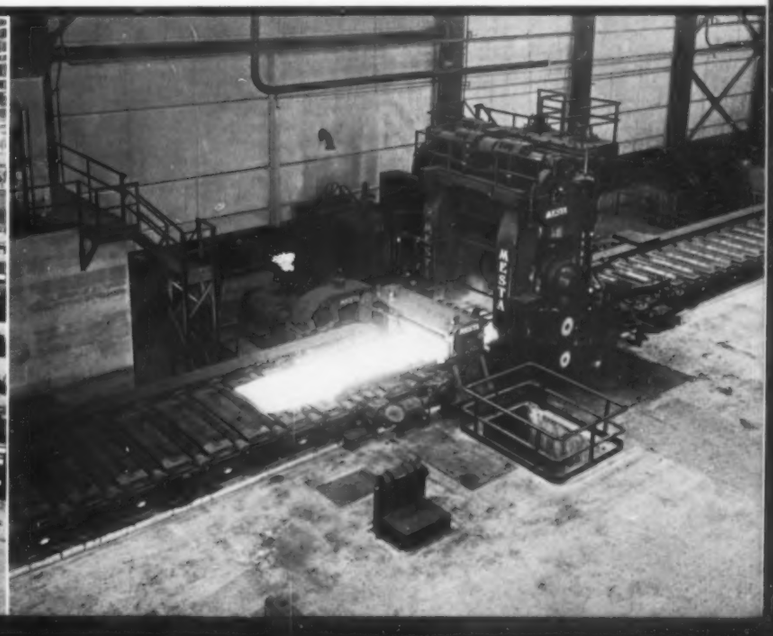
On leaving the furnaces, the hot slabs advance through a 2-high 36″ x 66″ scale breaker, driven by a 1250 hp. a-c. motor. Scale is removed by 1350 lb. water sprays. Next comes a 4-high spreading mill, equipped with turntables for rotating the slabs before and after rolling. This mill has 38″ x 130″ work rolls and 51″ x 124″ back up rolls and is driven by a 3500 hp. a-c. motor. After leaving the spreading mill, the slabs advance to the hydraulically operated squeezer, where they are squared up before further rolling.

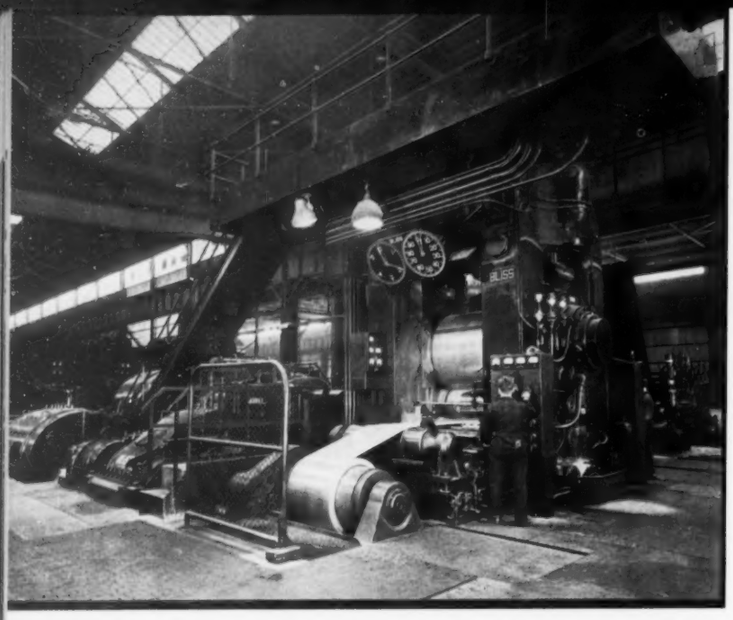
The No. 2 universal-roughing stand has work rolls 38″ x 81″ and 51″ x 76″ back up rolls and is driven by a 3500 hp. a-c. motor. No. 3 and 4 universal-roughing stands each have 34″ x 81″ work rolls and 53″ x 76″ back up rolls. 3500 hp. a-c. motors are also used on these stands. Two rotary crop shears are provided in the table between No. 4 roughing stand and the finishing scale breaker, where the front and tail crops may be sheared off as required. The piece is held on the approach table until its temperature is right for entering the finishing train. No. 2 scale breaker is a 2-high

Emerging from the finishing train, the strip passes over the runout table which is provided with water sprays for control of temperature.



This universal roughing stand, driven by a 3500 hp. motor, has 34″ x 81″ work rolls and 53″ x 76″ back-up rolls.





Delivery end of the four-high 20½″ and 53″ x 54″ reversing mill used for cold reduction of tinplate.

25½″ x 80″ mill, driven by a 500 hp. variable speed motor.

The finishing train consists of six 4-high stands equipped with 27″ x 81″ work rolls and 53″ x 76″ back up rolls. No. 5 and 6 stands are driven by 4500 hp. motors, Nos. 7, 8 and 9 by 5000 hp. motors, and No. 10 by a 2500 hp. motor, all being d-c. units, as are also the motors on the hot runout table. A rotary flying shear follows the last finishing stand to square up the head end of the strip or to cut it into sheets as desired. Strip leaves the last finishing stand at 1000 to 2000 feet per minute. The hot runout table is approximately 700 ft. long to the piler and scale, with two coilers located approximately 380 ft. from the last finishing stand.

The 80″ continuous hot strip mill is nominally rated at 600,000 gross tons per year of hot rolled strip in sheet or coil form.

The two coilers on the hot mill line discharge to short conveyors which transfer the hot coils to the 1270 ft. cooling conveyor. Down tilters discharging both right and left about midway down this conveyor line deliver coils to the raw coil storage rooms. A third down tilter is provided at the end of the conveyor line. Two 20-ton cranes, 120 ft. span, cover the main raw coil storage building, a third similar crane delivering raw coils from this storage building to the pickling lines.

The hot strip finishing department lies between the raw coil storage rooms at the end of the 80″ hot strip mill and the cold reduced finishing department. Provision is made for handling either strip or sheet as it comes from the 80″ mill. Equipment in the hot strip finishing department consists of flying shears, resquaring shears, temper mills, recoiling and side trimming lines, with a sheet pickler and scrubbing lines. Conveyors and transferring equipment have been installed so that the products of this department can be diverted to the various processing units with a minimum of handling.

Coils for cold reduction pass through either of two continuous pickling lines in the raw coil pickling department. This section of the plant connects to the South end of the raw coil storage building and extends East to the cold reduction department. One pickling line is designed to handle strip up to 38″ in width and the other will take coils up to 77″ in width. Gravity type conveyors receive the pickled coils from the recoilers and take them to a point from which tractors deliver them to the cold reduction department or storage as required.

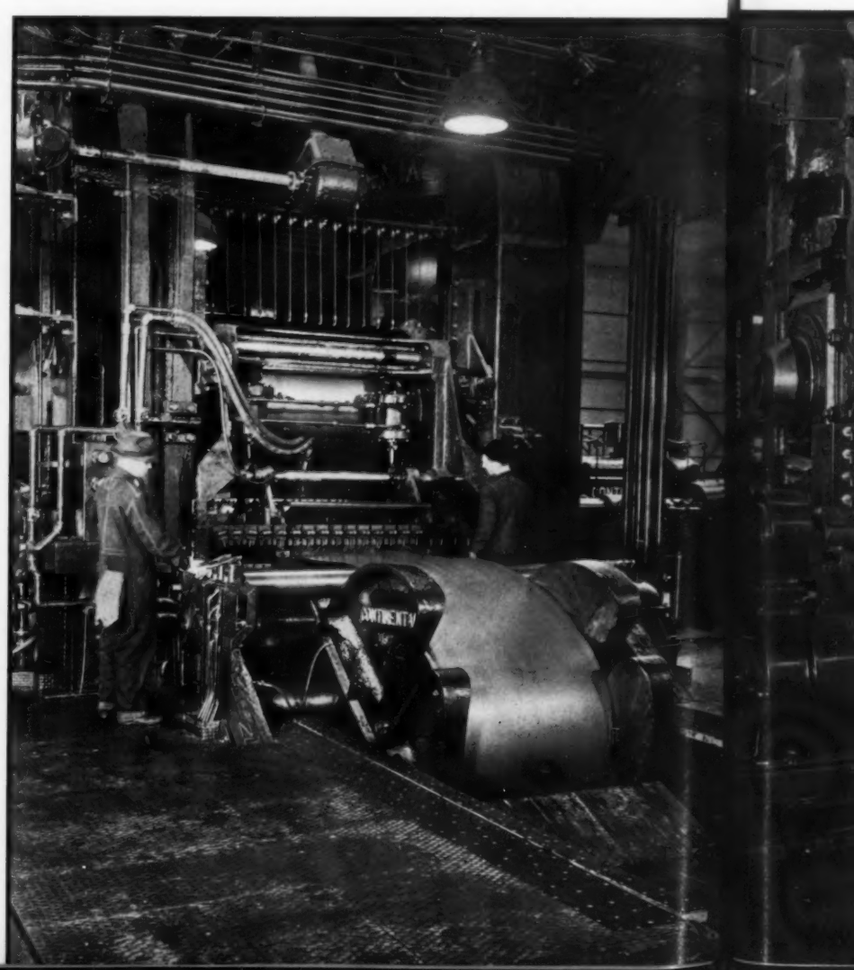
Here the flow lines split, part of the material swinging to the tin mill and part to the cold reduced sheet division.

COLD REDUCTION

Pickled coils for either black or tin plate are cold reduced in either a 5-stand tandem 4-high 20½″ and 53″ x 42″ mill or a 4-high 20½″ and 53″ x 54″ reversing mill. The 5-stand tandem mill, which has a rated capacity of approximately 100,000 gross tons per year, has a 600 hp. motor on the first stand and 1500 hp. motors on each of the remaining four stands. Strip speed ranges from 600 to 1565 feet per minute. This mill will handle stock from 16″ to 38″ wide in coils having a 20″ inside diameter and a 54″ outside diameter and in gauges from 14 to 30. The reversing mill is powered by a 3500 hp. motor and operates at a strip speed of from 500 to 1100 feet per minute.

From these cold mills the coils, which for the tin mill are from 16″ to 38″ wide, move on through three electrolytic cleaning lines to the tin annealing furnaces.

Entry end of the 20½″ and 56″ x 84″ tandem cold reduction mill, having an annual capacity of 200,000 tons of coiled strip.



Eleven gas-fired units are provided, with 36 bases designed to handle 16 coils per base when stacked two high.

Annealed stock is delivered by transfer cars to the tin temper mill department and then by tractor to the two 4-high two stand 18″ and 42½″ x 42″ mills, or to a single 4-high mill of the same size. These mills operate at strip speeds ranging from 600 to 1500 feet per minute, tempering strip from 16 to 38 gauge as required.

From these temper mills the coils move on to six flying shear lines. Four of the lines have shears of the reciprocating type and two have drum type shears. Special provision is made for disposing of the side trimmings and the sheared product is automatically gauge assorted.

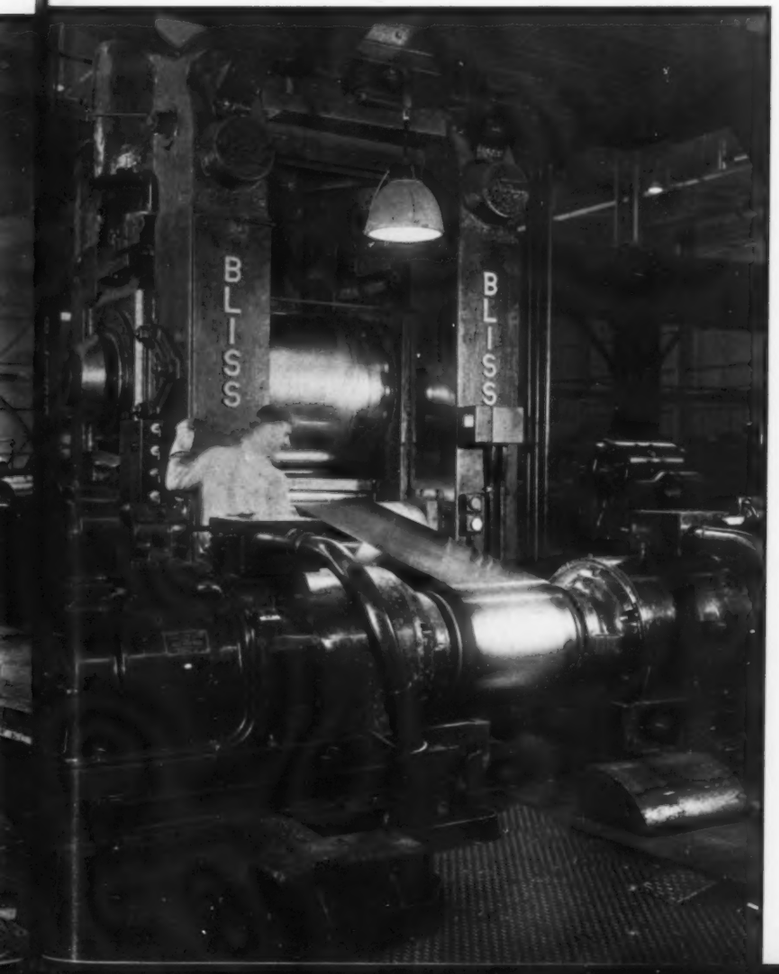
Sheared tin plate advances to the batch type white pickler and from there to the tin house, where 14 hot dip pots are installed, a continuous hood being provided over the entire battery to carry away fumes from the tin pots. Five of the tinning machines are 75″ units and the other 9 are 64″ wide. Tin plate is trucked to the assorting room, where it is closely inspected, weighed and boxed, moving on to the warehouse for storage or shipping. Material moves forward in a straight line at all times, never back-tracking.

Returning now to the cold reduction department, we find additional equipment for the processing of pickled coiled stock. In addition to the 5-stand cold reduction mill used for tin plate and the 4-high 20½″ and 53″ x 54″ reversing unit, which will handle coils from 18″ to 50″ wide, there is a 3-stand tandem mill 20½″ and 56″ x 84″, with a capacity of approximately 200,000 gross tons of coiled strip per year. No. 1 and No. 3 stands are each driven by 2500 hp. motors, No. 2 stand having a 3500 hp. motor. Delivery speeds from this mill range from 450 to 900 feet per minute, and it is designed to handle open hearth carbon steel, Bessemer steel, Cor-Ten, Man-Ten, Sil-Ten and stainless steel in widths from 18″ to 77″.

Cold reduced material from either of these mills is moved by crane or tractor to either a recoiler line, which side trims strip 16 gauge or lighter, or to three flying shear lines designed for strip 18″ to 77″ wide, 11 gauge or lighter. These lines, which are equipped with 2-high roller levelers, side trimmers and drum type flying shears, cut the strip into lengths ranging from 30″ to a maximum of 15 ft., operating at a speed of from 150 to 450 feet per minute.

Thirty-four muffle type gas-fired, controlled atmosphere annealing furnaces with 118 cases and hoods are installed in the cold reduced sheet and strip department. Two of these furnaces, each with three bases, are designed to handle coils up to 54″ outside diameter and widths up to 77″, each base providing space for eight maximum size coils set on end in two rows. The other thirty-two furnaces are designed for sheet annealing. Two 40-ton cranes and two 20-ton cranes, 120 ft. span, are available in this department.

Entry side of a two stand four-high 18″ and 42½″ x 42″ tin temper mill which operates in a speed range of 600-1500 ft. per min.



COLD FINISHING DEPARTMENT

After the annealing department comes the cold finishing department, in which there are provided three 4-high temper mills 20½″ and 48″ x 84″, two arranged for either coils or strip and one for sheet alone. These mills operate at a speed of 150-450 feet per minute. Two-high roller levelers are arranged in tandem with these mills. Also provided in this department is a 2-high 32″ x 84″ temper mill arranged for either sheet or coils, equipped with a 2-high roller leveler. Supplementing the mills is additional roller leveler equipment, a stretcher leveler, squaring shears, oiling machines, flying and resquaring shear lines, and a combination open annealing and normalizing furnace.

Every care has been exercised to assure maximum safety throughout the entire plant and special provision has been made for the comfort and convenience of the workers. Pickling, electrolytic cleaning, and tinning lines are covered or hooded to eliminate steam or fumes.

Convenient parking areas are provided near the main entrance to the plant and tunnels under the railroad tracks take the workers directly to the several buildings. Restaurant facilities are provided, as is also a completely equipped hospital. A 30-ft. roadway encircles the entire plant and a new road is being built to connect the plant with the state highway system. All shipping departments are provided with convenient truck loading space within the buildings, serviced by overhead cranes, as well as ample track space along car loading platforms.

A complete description of this plant will be published in the September, 1939 issue of the Iron and Steel Engineer.

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SPECIAL NOTICE

Annual Spring Conference

will be held in

BIRMINGHAM, ALA.

MARCH 27-28, 1939

Headquarters—
Hotel TUTWILER

Technical sessions on
Monday, March 27

All day inspection trip to
Tennessee Coal Iron and
Railroad Company
on Tuesday, March 28

Further Details Later

NEW ROLL LATHE DESIGN FEATURES ACCURACY AND SPEED

▲ With the ever-increasing growth of steel mills, and the constant demand for better surfaces on all rolled products, machinery for manufacturing rolls and steel mill equipment must also be improved to meet changing production requirements.

In order to furnish the trade with the proper kind of rolls to meet specifications of customers, Continental Roll and Steel Foundry Company undertook to develop a roll lathe equal to the demands of the present era. Obviously, radical changes in design and operation were necessary to cope with the larger rolls and greater accuracy rapidly coming into the high speed production picture. Since the new lathe had to do the job better, in less time, and at lower cost, Continental engineers took advantage of such modern developments as roller bearings, double helical cut gears, pressure lubrication, oil seals and unbreakable glass.

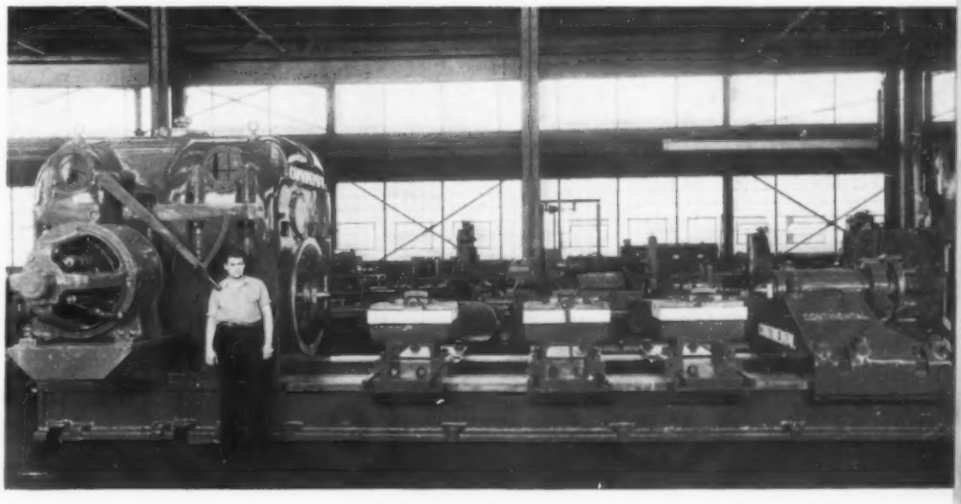
In developing the new lathe, Continental branched away from traditional features and has built a machine as different from the conventional lathe as the modern four-high strip mill is from the old style hand sheet mills.

The new lathe has no over-hung gears, no internal gears and pinions, no bronze bushings, no straight spur gears, and consequently no inclination to chatter, which is inevitable in the conventional roll lathes, yet so detrimental to roll surface. The usual protruding face plate is concealed with only the dog lugs extending beyond the face of the headstock. The over-hung pinion is replaced by a double helical pinion of generous proportions with roller bearing journals on each side. The customary internal gear has been converted into a double helical gear mounted on roller bearings. With all gears totally enclosed in the headstock, pressure lubrication from a centralized system is now applied to all moving parts to insure proper lubrication and perfect operating conditions at all times.

The headstock is equipped with inspection windows, which, with permanently enclosed interior lighting facilities, permits the operator to view all operating mechanism within the headstock at any time. The tailstock has been re-designed in keeping with the headstock and housings, and provisions incorporated to facilitate centering of the roll and moving the tailstock laterally to accommodate various lengths of rolls. The most recent engineering developments have been incorporated to eliminate chatter and produce a smooth, powerful machine for turning rolls of present day specification with the greatest degree of accuracy possible.

According to the manufacturer, the advantages derived emphasize the importance of this new development. Here is the first lathe to transmit the full power of the motor to the headstock; a broad statement, but proved in actual operation. Results indicate that with the new construction, a greater volume of better work can be obtained with finer accuracy and in less time than heretofore possible. And, Continental engineers point out, the new lathe will continue

This new roll lathe incorporates such features as roller bearings, double helical cut gears, and pressure lubrication.



to do this over a longer period because of its sturdy, generous design and construction.

NEW BLOOMING MILL FOR CANADA

▲ During the early part of 1937, one of the outstanding steel companies of North America, the Steel Company of Canada Limited, decided to proceed with an expansion program which had been carefully studied to increase the output of semi-finished steel for its widely diversified finishing mills and for future requirements.

Besides adding to the steel making capacity and modernization of the soaking pits, it involved the installation of an up-to-date 44-inch blooming mill.

For about twenty-four years all blooms had been rolled on a 34-inch two-high reversing blooming mill designed and built by United Engineering and Foundry Company of Pittsburgh, Pa., U. S. A. (with whom Dominion Engineering Company Limited is associated). In tandem with this 34-inch bloomer is a six-stand continuous sheet bar and billet mill.

The new 44-inch bloomer is located 190 feet from the 34-inch mill. To make room for this mill, four of the existing soaking pits had to be removed and four new ones installed adjacent to the remaining pits farthest from the mill.

The new mill is of the two-high reversing type with rolls 40 inches diameter by 96 inches barrel length. It is driven by a 7000 hp. motor through a fully enclosed pinion stand of 44-inch pitch diameter. The roll housings rest on cast steel shoe plates, the pinion stand directly on the foundation. The mill spindles are of the universal type. Considerable ingenuity was required to build an up-to-date mill in the available space. Particularly limited was the distance from end of motor to the end of the roll stand. It became necessary to place the pinion stand on the dividing line between mill building and motor house. Years ago mill operators would hardly have sanctioned such a location. Modern pinion stands, however, constitute such reliable units that no objection could be advanced to meet existing conditions in this manner. A drag-link coupling of proven design couples the motor to the pinion stand. Where space is at a premium and no misalignment need be considered, this coupling meets the requirements in the simplest possible manner.

The mill is essentially a duplicate of the blooming mill at the Ford Motor Company's plant at River Rouge, the blooming mill for Richard Thomas at Ebbw Vale and the recent installation at Cleveland, Ohio, for the Republic Steel Corporation. The latter mill, by the way, recently rolled 642 tons of slabs in three hours.

All details are of unusually rugged design. The mill screws are 15 inches diameter and are operated by two 150 hp. motors. The screwdown mechanism is mounted throughout on Dominion-Bantam roller bearings. The rolls as well as the top spindle are hydraulically balanced, a separate cylinder being provided for the spindle balance. This feature simplifies the foundation for the mill and adds greatly in ease of aligning top roll and top spindle when changing rolls. The method of roll changing is interesting Both rolls together with the roll neck bearings are pulled out simultaneously by an electric roll changing rig. The track of this rig extends into the adjacent roll shop.

The steel plant is located close to the bay where clean, cool water is available. It was decided, therefore, to use for the roll neck bearings phenolic rosin shells. Excellent results have been obtained by using this material on the existing 34-inch mill. Phenolic material is used also for the slippers of the universal joints of the mill spindles.

Ingots 20 inches by 20 inches weighing 6400 pounds had been the standard for the 34-inch mill. The standard ingot for the new mill is 25 inches by 27 inches weighing about

The new blooming mill, of two-high reversing type with rolls 46″ in diameter by 96″ length, increases plant rolling capacity materially.

10,000 pounds. This is usually rolled to about 10 inches by 10 inches before it passes on to the 34-inch mill. The mill, however, has sufficient lift to roll slabs 51 inches wide weighing about 17,000 pounds.

The reversing mill tables have rollers and lineshafts mounted on Dominion-Bantam roller bearings. The roller journal bearings at the lineshaft side are double row tapered, and at the opposite end cylindrical roller type, to allow for expansion of the table rollers. The lineshafts are carried in cylindrical roller bearings. End thrust of the lineshaft is taken up by a thrust bearing at the end of the shaft. By removing a filler the lineshaft can be moved endwise to put the bevel gears out of mesh for convenient removal of lineshaft or table rollers should this become necessary at any time. All gears and lineshafts are enclosed in an oil-tight trough which forms an integral part of the cast steel table girders.

The ingots, blooms and slabs are handled on the front and back mill tables by an electric double manipulator. One side guard on the side farthest from the soaking pits is equipped with tilting fingers. The operator's pulpit is located on this side of the mill, so that the men can have a view of the 34-inch mill, also. The manipulator is of the rack type with all driving mechanism on the spindle side of the mill. The racks and rack pinions have cut teeth. One rack is strong enough to take the full stalling torque of two 100 hp. motors. The racks are fastened to rolled steel rams between the table girders and outside of the table which travel on forged steel rollers. These rollers turn in roller bearings. Ample provision is made to prevent intrusion of scale and dirt into these bearings which are mounted in square seat boxes. These in turn rest on spreaders between the table girders. The arrangement is such that no bolts or keys have to be taken out for removal of the carrier rollers and boxes. Care has been taken to guard against accumulation of scale. The side guard which has the tilting fingers and its corresponding guard at the entry side of the mill have sufficient over-travel to permit removal of table rollers without disturbing the manipulator. The motor operated crankshaft drive for the tilting fingers is mounted on the foundation. In the design of this patented manipulator all sliding surfaces have been avoided except for backing up the tilting fingers.

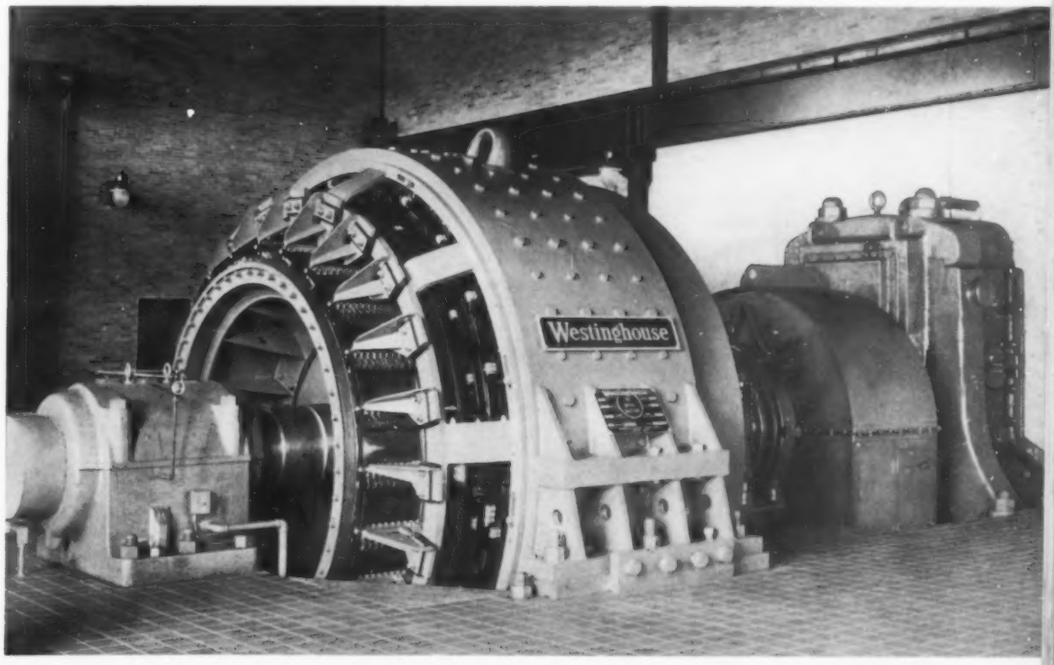
A knotty problem which had to be solved was the design of the ingot buggy. The old buggy which had fed the 34-inch mill was made for an ingot of 20 inches by 20 inches maximum section and travelled over a track of 36-inch gauge. Since two of the existing soaking pits were maintained, also part of the soaking pit building, the buggy had to be made to travel over the existing track and clear existing furnaces and building columns. It had to transport, however, a future ingot almost three times as large as the old one. Here modern manufacturing methods came to the rescue. Welded construction was applied except for the ingot pot proper. Instead of the customary automatic tilting by cam and lever, a motor operated crank mounted on the buggy does the tilting. It is pleasing to see the gentle way in which the ingot lands on the table.

After the ingot has been rolled down enough to be received by the 34-inch mill it is at times desirable to crop the ends before being delivered to this mill. Whatever means was to be used for this purpose had to be such that it would not interfere with the free passage of future slabs from the 44-inch mill and permit a free run-back during the last passes when small billets had to be rolled in the 34-inch mill.

To meet this condition a tilting horizontal shear was devised which, when inoperative, is depressed below the top of the adjacent tables. It is a clutchless machine with start-and-stop motor. It is self-contained, the rear end being hinged, the front end linked to a vertical hydraulic cylinder.

For dividing the blooms and slabs coming from the 44-inch and 34-inch

(*Continued on page 108*)



A 7000 hp. reversing motor drives the blooming mill through a fully enclosed pinion stand of 44″ pitch diameter.

"We avoided a rewiring job on our Grinder . . .
by installing
BUSS Super Lag
FUSES"!
BUSS
SUPER-LAG

SO SAYS:—*Mr. Arthur Holmes, Chief Electrician, Ingersoll Milling Machine Co., Rockford, Ill.* "Shutdowns were occurring an average of five times weekly on temporary starting loads on a grinder powered by a 20 H.P., 220 V. three phase squirrel cage motor fused with ordinary renewable fuses of 100 amp. capacity.

"Severe production penalties due thereto caused me to install 100 amp. BUSS SUPER-LAG FUSES, along about the first of this year, and to date we haven't had a single fuse blow on this circuit.

"Not only have we disposed of the annoyance and expense entailed by the former situation but we were saved the cost of installing a larger sized switch, with larger fuses, which surely would have been necessary had we continued with ordinary fuses."

Avoiding Installation Costs Is Only a Part of the Savings Buss Fuses Can Make in Your Plant

The big saving with BUSS Super-Lag Fuses comes from the elimination of needless blows with their resultant costly shutdowns.

Prevention of needless blows is accomplished thru two scientifically worked out features:—

1. The design of the FUSE-CASE is such that it guards the fuse link against possible injury while renewing the fuse—and it MAKES and MAINTAINS good contact on the fuse link.

Given good contact in the clips, a BUSS fuse will carry continuously its full rating. Users are not annoyed by fuses blowing because of faulty design.

2. The Super-Lag development in the FUSE-LINK gives BUSS fuses a time-lag sufficient to hold harmless overloads such as those caused by two or more motors starting simultaneously or a machine not getting up to speed quickly or other such common condition.

With BUSS Super-Lag fuses the circuit is not shut down needlessly—useless shutdowns that cause machines and workers to stand idle are avoided.

For a comparison of the BUSS design with others ask for a free copy of the "Rb" book—or better still...

Give your plant this low cost protection, by passing the word down the line that all purchase orders and requisitions must call for BUSS Super-Lag Fuses.

BUSSMANN MFG. CO.
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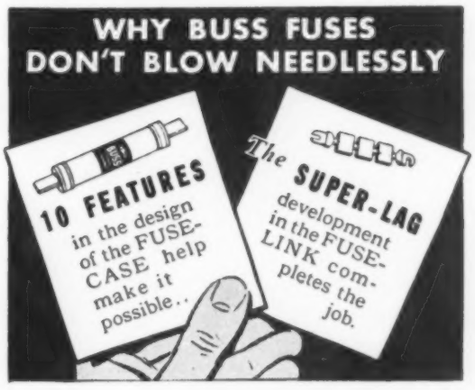

WHY BUSS FUSES DON'T BLOW NEEDLESSLY
10 FEATURES in the design of the FUSE-CASE help make it possible..
The SUPER-LAG development in the FUSE-LINK completes the job.

BUSS *Super Lag* FUSE

mills a patented shear of nove ldesign has been furnished as part of this contract.

The shear proper consists of a bottom knife block, a top knife block, a crankshaft centered in the bottom knife block, a pin in the top block and two interconnecting links which absorb all the shearing stresses. A simple frame takes up the external torsional moment. Power is transmitted to the crankshaft from an independently mounted gear drive through a universal spindle.

In operation, the top knife block first descends on the material to be cut and forming thereby a simple gag, then completing the stroke, the bottom block, so to speak, pulls itself up by its own boot straps. It is evident, therefore, that the actual cutting stroke is limited to the thickness of the material which is to be cut, plus the small overlap of the knives. The whole arrangement is exceptionally sturdy and makes a neat appearance. Modern lubrication methods protect the crankshaft from scale intrusion. The guides are protected by guards which form an integral part of the bottom block. The compactness of the mechanism allows a minimum amount of obstruction of view over and around the shear.

The shear can exert a pressure between the knives of two million pounds.

The mill was put in operation on April 17th, 1938. The first ingot was finished to the sheet bar. During the first eight hour turn an average of 70 tons per hour was rolled, not a record output, but unusual in starting up a new mill of this kind.

TRIPLE SEAL EFFECTIVELY PROTECTS BEARING

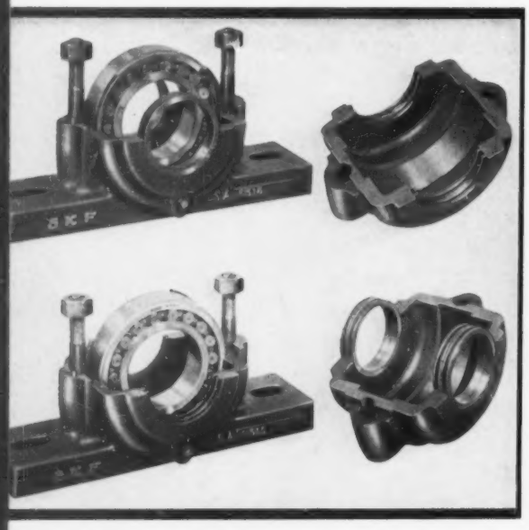
▲ A patented triple seal which effectively protects the bearing against lubricant leakage, dust, dirt, and moisture has been made available by SKF Industries, Inc., Front Street & Erie Avenue, Philadelphia, Pennsylvania.

This seal consists of two split piston rings on each side of the housing and grooved on the outside diameter to form a labyrinth seal with the two end bores of the housing. Each ring has an inward tension that enables it to turn with the shaft. On either side of the housing, two rings are mounted on the shaft with the splits 180 degrees apart to prevent lubricant leakage through the splits. The inner ring serves as an internal flinger, and the outer ring keeps dirt and other foreign substance from entering the housing. Because these rings are not securely fastened to the shaft, the seals are free to locate themselves axially whenever shaft expansion occurs. Consequently, close clearances are maintained at all times between the rings and the housing.

Made of cast iron, the rings are hammered on the outside diameter in order to obtain the required inward tension to hold them properly on the shaft. If any lubricant should pass the first seal, it is returned into the housing through a hole located in the center groove of the bottom half of the housing. The lubricant is returned at a point below the oil level. The triple seal is made for the complete range of standard shaft sizes, and is designed for split housings which are machined to allow axial freedom of the bearing. These housings are sturdy and designed to accommodate various shaft diameters which are necessary to compensate for the various types of bearings having the same outside diameter.

Another unique advantage is that when a bearing is to be stabilized, the same housing is used as for the floating bearing. The stabilizing is effected by one or two rings depending on the width of the particular bearing used. A segment of the ring is removed so that it can be slipped over the shaft and applied between the outer race of the bearing and the housing shoulder. This avoids the necessity of supplying two different housings and enables the user to stabilize or float any one of the bearings in any application.

Two split rings on each side of the housing form an internal and external seal for the bearing.

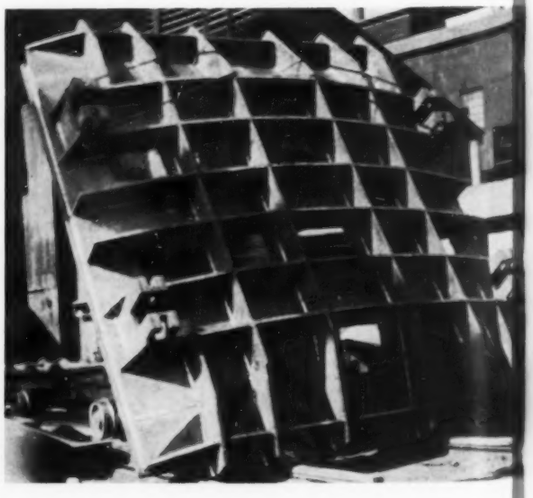


ALL-WELDED DESIGN OF SOAKING PIT COVER

▲ In the $200,000 program sponsored by the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio. A. R. Mitchell and H. Q. Gruell, of the Andrews Steel Company, Newport, Kentucky, received an honorable mention award of $101.75 for a design of soaking pit cover as shown in the accompanying illustration.

The cover is constructed entirely of rolled steel products burned or bent to the required size and shape, and assembled entirely by means of arc-welding. The curving of the 1¼" steel bars which form the arched top of the cover is accomplished by means of a bending jig, using the flame-cut

View of fabricated soaking pit cover formed entirely from rolled steel products burned or bent to size and shape.



curved transverse ribs as part of the jig.

The estimated cost of one welded cover of this type, 14′ 4½″ long by 11′ 10⅜″ wide, is as follows:

Burning, bending and fabricating	$ 190.55
Supervision and welding	341.70
Machine and blacksmith shops	30.90
Welding and cutting materials	188.70
Rolled steel products	525.00
Total Cost	$1276.85

SOOT AND FLYASH HANDLED BY SUCTION

▲ Believed to be the first device of its kind mounted on a trailer to be powered by electricity, a new suction cleaner has been developed by the Carl E. Swift Corporation, Holland, Michigan, for removing soot and fly ash from furnaces, chimneys, and boilers. Soot is well-known as an effective heat insulator. It is claimed that one-eighth inch of soot upon one-quarter inch of cast iron will reduce heat conductivity by radiation as much as 50 per cent. To manufacturers, this means reduced heating-plant efficiency; to home owners, it means a waste of fuel with a lack of heating comfort; to coal dealers, it means a lot of complaints about "poor coal". The cleaning of furnaces and boilers, therefore, is quite essential to efficient heating and, in this regard, the new Swift suction cleaner should prove highly popular. The usual cleaner of this type has, in the past, been powered by a gasoline engine.

Driven by a General Electric 1725-rpm., a-c. repulsion-induction motor, the Swift cleaner is a self-contained unit built into a small trailer about eight feet long. The suction bag itself, when inflated, is 33-feet long and six feet in diameter.

An unusual-type fan arrangement is employed in the equipment. Two sets of blades, one straight and one curved, are used. The straight blades, which are of small diameter, are so arranged that high velocity air movement is obtained at the intake with extremely low power input. The air is then picked up by the curved blades, which have a larger diameter, and discharged through an orifice of such dimensions that back pressure in the bag is avoided. The fan is mounted directly on the motor shaft, thus eliminating the necessity for belts and gears and, as the motor and fan are the only moving parts, they are the only portion of the equipment subject to wear in operation.

All flexible hose, metal pipe, brushes, scrapers, and other necessary accessories for fast and efficient cleaning are furnished with the unit.

BELT CONVEYOR ON TEMPER MILL

▲ In the modern steel mill, it is usually desirable that the same temper mill be available for the finishing pass on material either in sheets or coils. For feeding the sheets to such a mill, a belt conveyor is best adapted because it does not mar the surface of sheets. Where there is considerable variation in width of sheets, it is imperative that means be provided for centering them with respect to center line or mill. This would be a simple matter if the feed table could be the usual type of chain driven live roller conveyor because adjustable guard rails could be used with guard rail supports moving in and out between the rolls.

The accompanying photograph show how the Logan Company's engineers adapted adjustable guards to belt conveyors handling sheets varying in width from 30″ to 94″. The plant is the newest of the larger sheet mills. The machine served is known as a combination cold strip and sheet mill. The middle belt of this triple-belt conveyor is stationary and located on the center line of mill. Each of the outer belts is integral with its guard rail and is adjustable laterally through right and left hand screws by means of the hand wheel visible in both views; the head pulleys of outer belts are mounted on splined shafts. Sheets are fed manually to belt conveyor from the pack tilter shown at right.

The belt conveyor is provided with lifting rings at the corners and is lifted bodily out of the way when it is desired to feed coiled strip to the mill. The coils are deposited by crane on the roller conveyor. The roller conveyor delivers to a combination down and side tilter from which coils roll off to skids leading to uncoiler.

Coils are delivered by the roller conveyor to a combination tilter from which they roll off to the uncoiler.

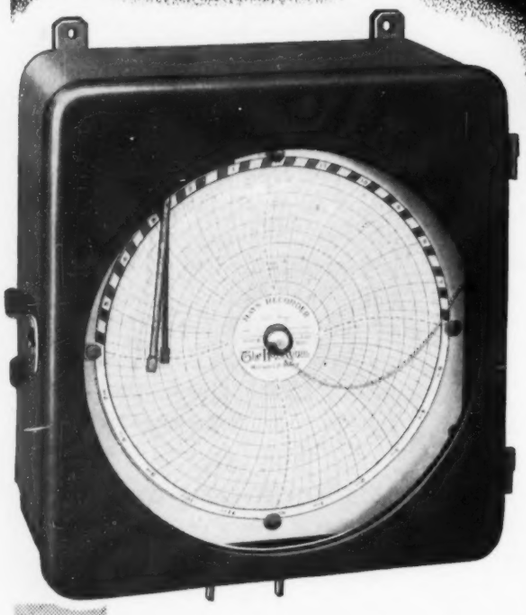
YOUNGSTOWN SHEET & TUBE CO. AND WHEELING STEEL CORP. PLACE LARGE EQUIPMENT ORDERS

▲ Youngstown Sheet and Tube Company recently gave orders for several large pieces of steel mill equipment, involving millions of dollars. This equipment is to be installed in the East Chicago, Indiana, works of that company. Mesta Machine Company has received an order to construct a 56″ hot strip mill. United Engineering and Foundry Company will construct a four-high tandem cold strip mill, and a 45-46 inch blooming mill at its Youngstown, Ohio, plant.

Electrical equipment for this new addition to the Youngstown Sheet and Tube Company's plant will be supplied by Allis-Chalmers Manufacturing Company, Westinghouse Electric and Manufacturing Company, and General Electric Company.

▲ Wheeling Steel Corporation recently announced that construction would be started immediately on four new galvanizing units at its Steubenville, Ohio, plant. It is the Wheeling Steel Corporation's plan to add additional units at a later date.

FURNACE ATMOSPHERES *Accurately Checked*



HAYS "OT" DRAFT RECORDER

In the steel industry the HAYS Super-sensitive OT Draft Recorder is invaluable for maintaining proper atmospheres in soaking pits, annealing furnaces, open hearth furnaces, slab-mills—any place where an accurate record of Draft, Pressure or Differentials is required. Sensitive enough to register accurately increments of .0025 of an inch water pressure yet husky enough to withstand the jars and dirt of mill operation. Cut shows case for lug mounting on wall; made also for flush panel mounting and with carrying handle for spot testing. Measuring unit is the famous Hays Slack-leather Diaphragm—fool proof, long lasting. Two draft values, two pressure values, two differential values or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write Dept. 7-12-8.

The HAYS CORPORATION
SINCE 1903 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

GRANITE CITY ADDS NEW ROLLING UNIT

▲ Granite City Steel Company, Granite City, Illinois, has started installation of an annealing and temper rolling unit, costing $1,500,000 to $3,000,000. This is part of an improvement program begun in 1935, including additions to buildings and installation of two cold strip and a hot strip mill. Construction of the new unit will require about four months.

Cost of the complete expansion program will be about $5,500,000. It will enable production of sheet steel of any marketable gage and a larger output of tin plate.

KOPPERS CONSOLIDATE TWO SUBSIDIARIES

▲ Koppers Company's Western Gas division, Fort Wayne, Indiana, has been absorbed by its Bartlett Hayward division, Baltimore. Sales and engineering activities at Fort Wayne have been moved to Baltimore, where they will be consolidated with the Bartlett Hayward organization.

This move is another step in the process of corporate simplification which was started by Koppers Company two years ago. The consolidation brings two of Koppers Company's major manufacturing divisions under single management, a step, which it is stated, will enable the organization to provide its customers with more complete sales, engineering and manufacturing service.

NEW LITERATURE

▲ De Laval Steam Turbine Company has issued a 36-page illustrated catalog describing single suction multi-stage pumps. In this type of cen-

trifugal pump, which is widely used for feeding high pressure steam boilers and other high pressure service, the individual impellers are unbalanced axially, necessitating the use of a thrust bearing or else some form of hydraulic balancing device. In this pump, this is a disc subject to discharge pressure upon one side and to an automatically controlled reduced pressure upon the other and having close axial clearance, but no contact, with the casing.

Readers desiring copies of this catalog B-5, should write to the De Laval Steam Turbine Company, Trenton, New Jersey.

▲ Morgan Construction Company recently published an attractively designed booklet describing Morgoil roll neck bearings. This booklet tells of the development of Morgoil bearings from the time of its inception to the present. Charts showing sizes and capacities of Morgoil bearings, pictures of various installations, and numerous other valuable data is included in this booklet.

Anyone wishing to obtain this bulletin should write to the Morgan Construction Company, Worcester, Massachusetts.

▲ Crane Company issued recently an elaborately designed 50-page book which tells about the Crane Research Laboratories. These research laboratories have been arranged to cover almost every related field of the design and development of the products of the Crane Company. Descriptions of each separate field are written, in this book, in an interesting manner with appropriate illustrations.

Interested persons should write the Crane Company at 836 South Michigan Avenue, Chicago, Illinois.

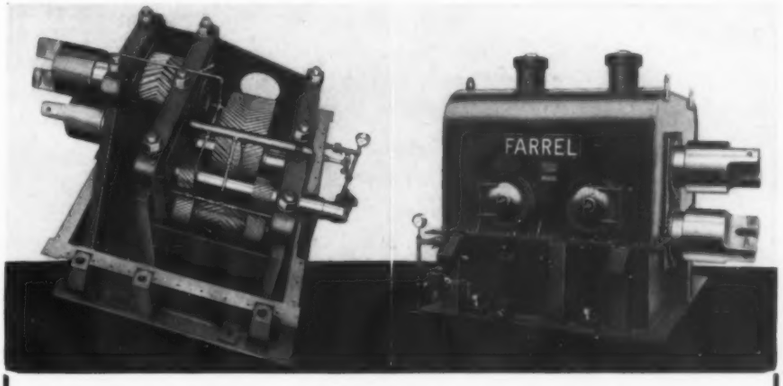
▲ Industrial Gas Engineering Company, Inc., manufacturers of high temperature air handling equipment and industrial oven and furnace heating equipment, has issued a 54-page bulletin complete with diagrams and tables describing methods of using convected heat. This catalogue should prove a valuable addition to your file on steel mill catalogues.

Write direct to the Industrial Gas Engineering Company, Inc., 201 East Ohio Street, Chicago, Illinois.

▲ Lincoln Electric Company has on file a comprehensive 20-page booklet giving the story of the new arc welding technique made available by the "Shield-Arc" welder with self-indicating dual continuous control. This bulletin discusses in detail the operation of welder control, interpreting the electrical performance in terms of mechanical welding results.

If you desire a copy please write to the Lincoln Electric Company, 12818 Coit Road, Cleveland, Ohio.

▲ C. J. Tagliabue Manufacturing Company, instrument manufacturers, has available for distribution a bulletin on indicating, recording and controlling instruments for temperature pressure. Bulletin No. 1178 completely illustrates and describes this company's recorders and recorder-controllers. Copies may be obtained by writing C. J. Tagliabue Manufacturing Company, Park and Nostrand Avenues, Brooklyn, New York.



WELDING SOLVES PROBLEMS of DELIVERY and DESIGN

A short delivery was required on six of these drives and no patterns available for the case. The difficulty was overcome by welding the cases of rolled plate, with steel castings for the bearing chocks and caps and foundation bolt columns.

Welding also permitted location of light and heavy sections as required without the limitations that an abrupt change of section imposes on cast structures.

The two views of the drive above illustrate the relatively simple design of the interior for mounting the gears and bearings and the rounded contours possible in a fabricated structure.

Other features of these Drives are the integral pinion unit for direct connection to the mill, the Farrel-Sykes continuous tooth herringbone gears and mill pinions and anti-friction roller bearings. The gears are lubricated by built-in sprays and the bearings are flood lubricated, oil being supplied to both gears and bearings by a central lubricating system. The breathers mounted on the cover prevent oil contamination by trapping dirt and moisture.

Farrel Drives are designed and built "to fit the job". Since we are equipped to make both cast and welded structures, a recommendation of either, or a combination of both, is made in the interest of the customer and is not prejudiced by manufacturing limitations.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

ITEMS OF INTEREST

Russel O. Hunt was named assistant superintendent, rolling mill in charge of steel preparation, for the Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania. Other changes at the Duquesne Works are as follows:

Dennis A. Crowley is now the assistant chief metallurgist in charge of inspection and testing;

Edward J. Chelius as assistant to superintendent open hearth department in charge of electric furnace steel production.

▲

Carnegie-Illinois Steel Corporation recently announced the following titles of supervisory personnel in the engineering department at the Homestead, Pennsylvania plant:

G. M. Miegs as chief design engineer;
R. F. Gellert as project engineer;
M. M. Marks as power and fuel engineer;
W. J. Leslie as appropriation control engineer;
C. O. Franklin as electrical engineer;
H. F. Ramsey as construction engineer; and,
M. H. Van Cleve as office engineer.

▲

Dr. Walter C. Rueckel has joined the staff of Battelle Memorial Institute as research engineer. Dr. Rueckel, who has been with the Koppers Company for the past three years, will be engaged in ceramic research, a field in which Battelle is particularly active.

A graduate of Ohio State University in 1929, Dr. Rueckel was for four years research engineer at the Ohio State University Engineering Experiment Station. In 1933 he received the degree of Ph. D. from that university.

George Wheeler Wolf was recently appointed president of the United States Steel Products Company, effective January 1, 1939. This company is the export medium for the United States Steel Corporation. Mr. Wolf succeeds George C. Scott, who is retiring from active service but will remain with the company in the advisory capacity.

Mr. Wolf, at present operations manager of the General Motors overseas operations, is well known in export circles of the automotive industry. He was born in Pittsburgh, Pennsylvania, in 1892 and was appointed to the Naval Academy in 1909. He was graduated in 1913, and served in the navy until his resignation in 1926 as a lieutenant commander. For the next thirteen years Mr. Wolf was with General Motors Corporation, spending ten years abroad.

▲

D. J. Richards has been appointed manager of steel mill sales for E. F. Houghton and Company, Philadelphia, Pennsylvania. Mr. Richards was a divisional sales manager for this company and will retain his headquarters in the Bessemer Building, Pittsburgh, Pennsylvania. He had more than twenty years' experience as a supplier to the steel industry while with E. F. Houghton and Company, and prior to that time spent a number of years in steel mill service. His new duties will include promotion and service on products which this company supplies to the steel mill industry. Mr. Richards is a graduate of the University of Pittsburgh, having studied mechanical engineering and metallurgy.

▲

E. H. Heilstedt was named assistant to the superintendent of industrial relations for Carnegie-Illinois Steel Corporation's Gary Works. Mr. Heilstedt has

DR. WALTER C. RUECKEL

GEORGE W. WOLF

D. J. RICHARDS

been associated with Carnegie-Illinois Steel Corporation since August, 1915, when he started as a clerk in the storehouse at the Gary plant. A year later he was promoted to the post of chief clerk in the machine shop and served in this capacity until 1928, when he was appointed assistant superintendent of employment. In September, he was advanced to the superintendency of employment and remained in this position until his current appointment.

▲

A. H. Kofoed is now the director of personnel and employment at the Gary Works of the Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Kofoed began service with the corporation on March 9, 1936, as director of personnel and employment at South Works, and continued in that position until his promotion to Gary Works. Prior to his employment at South Works he was connected with various phases of personnel work in the industrial field.

▲

Avery C. Adams has been appointed vice-president and assistant general manager of sales of Inland Steel Company, Indiana Harbor, Indiana. Mr. Adams

AVERY C. ADAMS

will be in charge of the sale of all Inland's sheet and strip steel products. Formerly manager of sales, sheet division, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania, Mr. Adams has been identified with the steel industry since 1919 when he joined Trumbull Steel Company, Warren, Ohio. After working three and a half years in the mill, he subsequently became district manager of sales, and later assistant general manager of sales. He became manager of tin plate sales for the Republic Steel Corporation, when Trumbull merged with Republic. In July, 1928, he joined the General Fireproofing Company becoming vice-president in charge of sales and director. In 1936, Mr. Adams became affiliated with the Carnegie-Illinois Steel Corporation as manager of sales in the sheet division.

H. S. Norton has retired from the vice-presidency of the Gary Land Company, after serving thirty-nine years with subsidiary companies of the United States Steel Corporation. Mr. Norton, who graduated from De Pauw University, Greencastle, Indiana, in 1888, started his business career at Lockport, Illinois, with his father's firm, Singer and Norton Stone Company. Later he became associated in an executive capacity with the Western Stone Company of Lemont, Illinois, and the Norton Stone Company, Bloomington, Indiana. He went to Gary, Indiana, in 1907, less than a year after the United States Steel Corporation began construction of the mills there and at a time when the site of the present city was still a wilderness of sand dunes. Previously, he had served with the Corporation's subsidiaries for eight years beginning in 1899 with the Illinois Steel Company at Joliet, Illinois.

▲

Howard V. Clark was made manager of sales in the sheet division for Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Clark, for-

HOWARD V. CLARK

merly general manager of the order division, will succeed Avery C. Adams, resigned.

Mr. Clark, a graduate of the United States Naval Academy at Annapolis and a former officer of the Navy, began his business career with the former Carnegie Steel Company in 1927. He became assistant manager of sales for the Detroit district in 1932, and has been general manager of the order division for Carnegie-Illinois since October 1936.

▲

J. B. Emory has been named manager of the new district office of the Combustion Engineering Company, Inc., recently opened in Birmingham, Alabama. Mr. Emory has been associated with the Combustion

Engineering Company for several years in shop management and sales capacities. W. E. Johnson will be the assistant district manager. The office will be located in the Martin Building, Birmingham, Alabama.

▲

Charles A. Ferguson has been transferred from the Farrell Works of the Carnegie-Illinois Steel Corporation, Farrell, Pennsylvania, to the Gary Works at Gary, Indiana. Mr. Ferguson will be assistant general superintendent of the sheet and tin mills.

Mr. Ferguson entered the employ of the United States Steel Corporation in 1913 as assistant master mechanic at the Vandergrift, Pennsylvania, plant. In 1918, he was transferred as master mechanic to the tin plant of the former American Sheet and Tin Plate Company, at Farrell, serving until January 1927, when he was named assistant manager. With the consolidation in 1932 of the sheet and tin plants, he continued as assistant manager. In 1935 he was advanced to manager, and when Carnegie-Illinois Steel Corporation merged the management of its tin, sheet and steel plants in 1937, he was made assistant general superintendent.

▲

E. P. Aldredge, formerly general superintendent of the National Works, Carnegie-Illinois Steel Corporation, Monessen, Pennsylvania, succeeds Charles A. Ferguson as assistant general superintendent of the Farrell Works, in direct charge of tin operations.

Mr. Aldredge has been in the employ of the United States Steel Corporation for thirty-five years, serving plants at New Castle, Martins Ferry, and Vandergrift.

▲

John N. Marshall, assistant general manager of the fabricated steel department, Bethlehem Steel Company, Bethlehem, Pennsylvania has been elected to the board of trustees and executive committee of Koppers United Company.

R. H. McClintic, assistant to the president of Koppers Company, in charge of advertising and sales promotion, was also elected to the board of trustees and executive committee of the Koppers United Company. Mr. McClintic came to the Koppers Company from the McClintic-Marshall Corporation in 1931, and was made assistant to the president in 1936.

▲

Frederick J. Griffiths and **K. Bert Bowman** president and vice-president respectively of the Griffiths-Bowman Company, Massillon, Ohio have become associated with the Aetna-Standard Engineering Company of Youngstown, Ohio, through the recent affiliation of those two companies. Mr. Griffiths and Mr. Bowman will be located in the Merchants Trust Building, Massillon, Ohio.

▲

C. E. Herington has been appointed director of publicity and advertising manager by the Meehanite Research Institute of America, Pittsburgh, Pennsylvania. Mr. Herington, who was previously connected with a Pittsburgh publicity organization, will conduct an advertising and publicity program for Meehanite Metal.

We are in need of the following yearbook volumes to complete our permanent files—1907 to 1918 inclusive; 1920; 1925 and 1927.

We will be very glad to have the membership adivse us just what volumes they care to contribute and we will then state definitely what we require so as to prevent too much duplication. All expense incurred by a donor will be defrayed by the Association. Please give this request your earnest and prompt attention.

▲

Obituaries

Phil Schaum died recently in his home at Pittsburgh, Pennsylvania. Mr. Schaum was well-known in the Pittsburgh district having been located in that area for many years representing V. V. Fittings Company. For several years he had been affiliated with the Association of Iron and Steel Engineers.

▲

William R. Ottey, who was employed by Rumsey Electric Company, died recently in his home at Upper Darby, Pennsylvania. Mr. Ottey was a member of the Association of Iron and Steel Engineers.

▲

B. E. V. Luty died recently in his home at Pittsburgh, Pennsylvania. Mr. Luty was recognized as one of the best informed persons in the nation on the statistics of the steel industry. For more than 25 years he was a contributor to the financial pages of local newspapers and for a like period wrote editorials and market reports for the AMERICAN METAL MARKET. He spent fifty years gathering data and observing the growth of the steel industry and had one of the most complete libraries on the subject.

Born in Pittsburgh, sixty-eight years ago, he was graduated from the University of Pittsburgh in 1891, receiving the degrees of A. B. and Ph. D. at the same time. In 1887 he added Dr. Samuel P. Langley in the investigation of aerodynamics at Allegheny Observatory. Soon after he began work as a draftsman with the old Carnegie-Phipps Company. In 1892, he became mechanical editor of TIN AND TERNE, later its owner and editor until 1902.

▲

Raymond S. Gough, 59, office manager of Carnegie Land Corporation since 1927, died suddenly at his home recently. Mr. Gough had been associated with subsidiary companies of the United States Steel Corporation for forty years preceding his death.

▲

William J. Brady, 44, assistant secretary of H. C. Frick Coke Company and its affiliated companies, died at his home in Pittsburgh, Pennsylvania. Mr. Brady came to Pittsburgh from Danville, Illinois, ten years ago as secretary to the president and has been assistant secretary for the past three years.

EVEN LUTHER BURBANK *Couldn't make* ROCKBESTOS "BLOOM"

The old horticultural magician, if he were alive today, could saturate a Rockbestos insulated cable with all kinds of oil—rub it down with thick gooey grease—day after day—but he'd never be able to make it "bloom."

Rockbestos insulation, made of inorganic asbestos is inert to the blooming, swelling and rotting action of oil, grease and corrosive fumes. It has greater resistance to insulation-destroying agents than any other type of wire you can buy, and in addition is absolutely heatproof and fireproof. Coal mines, refineries, chemical plants, heat-treating and engine rooms are only a few of the places where Rockbestos is used in permanent, money-saving installations.

If the wire you are now using is failing under severe conditions replace it with Rockbestos. If you want to try before you buy send for test samples. Rockbestos Products Corporation, 906 Nicoll St., New Haven, Conn.

IF YOU HAVEN'T SENT IN FOR YOUR COPY OF THE NEW NO. 10-E BULLETIN . . . WRITE TODAY!

ADEQUATE WIRING SERVES AND SAVES

OTHER ROCKBESTOS FEATURES

IT HAS GREATER CARRYING CAPACITY

Rockbestos' greater carrying capacity saves conduit replacement, labor and money.

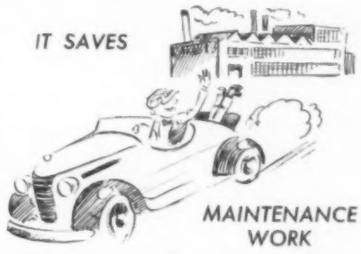
IT IS HEATPROOF

Rockbestos insulation, made of asbestos, does not deteriorate under heat. It's flameproof, too.

IT IS PERMANENT

Rockbestos is always "as good as new" because asbestos is naturally time-resistant.

IT SAVES



MAINTENANCE WORK

Rockbestos wired circuits eliminate frequent and expensive replacement.

IT IS VIBRATION-PROOF

Rockbestos insulation won't dry out, crack, open up, or fall off.

RUPTORS QUENCH ARCS *FAST!*

Their "QUICK-QUENCH" Action CUTS Oil Carbonization and Contact Deterioration to a Minimum!

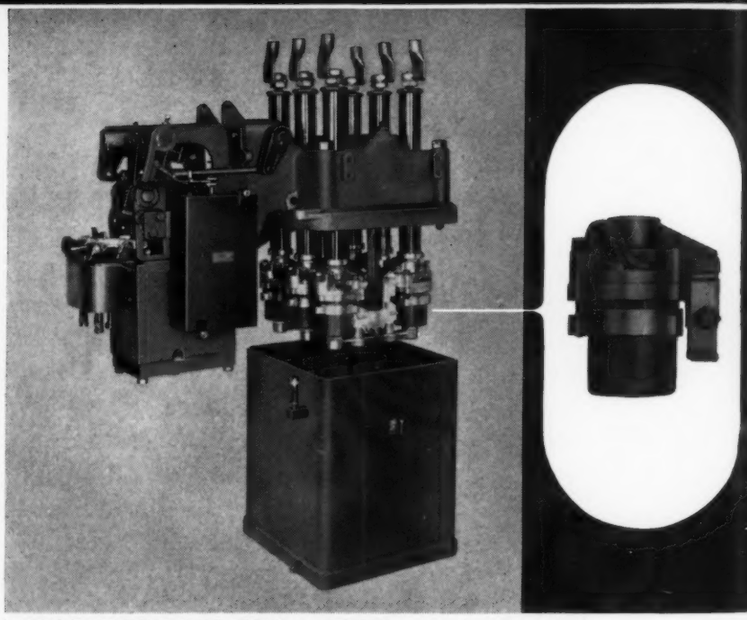
● When a short circuit occurs, it's got to be interrupted in a hurry! That's the *why* of the oil circuit breaker. That's what you get in Allis-Chalmers Oil Circuit Breakers with Ruptors, for high voltage systems.

For Ruptors snuff out arcs . . . *fast*! And their "QUICK-QUENCH" action means that oil carbonization is lessened and contact replacements are reduced . . . that high maintenance and inspection costs are actually cut to a minimum!

Consistent Operation Without Constant Attention!

You get consistent operation without constant attention. Ruptors enable an oil circuit breaker to handle many more circuit interruptions before requiring inspection and renewal of oil and contacts. And when service is necessary, it's a quick and easy job! Ruptors are accessible for inspection and testing . . . take less time to service than other circuit breakers.

But that's not all you get when you install Allis-Chalmers Oil Circuit Breakers. You get the advantages of Allis-Chalmers experience in engineering. You benefit by the technical research continually in progress in the Allis-Chalmers laboratories and in those of associated companies throughout the world.



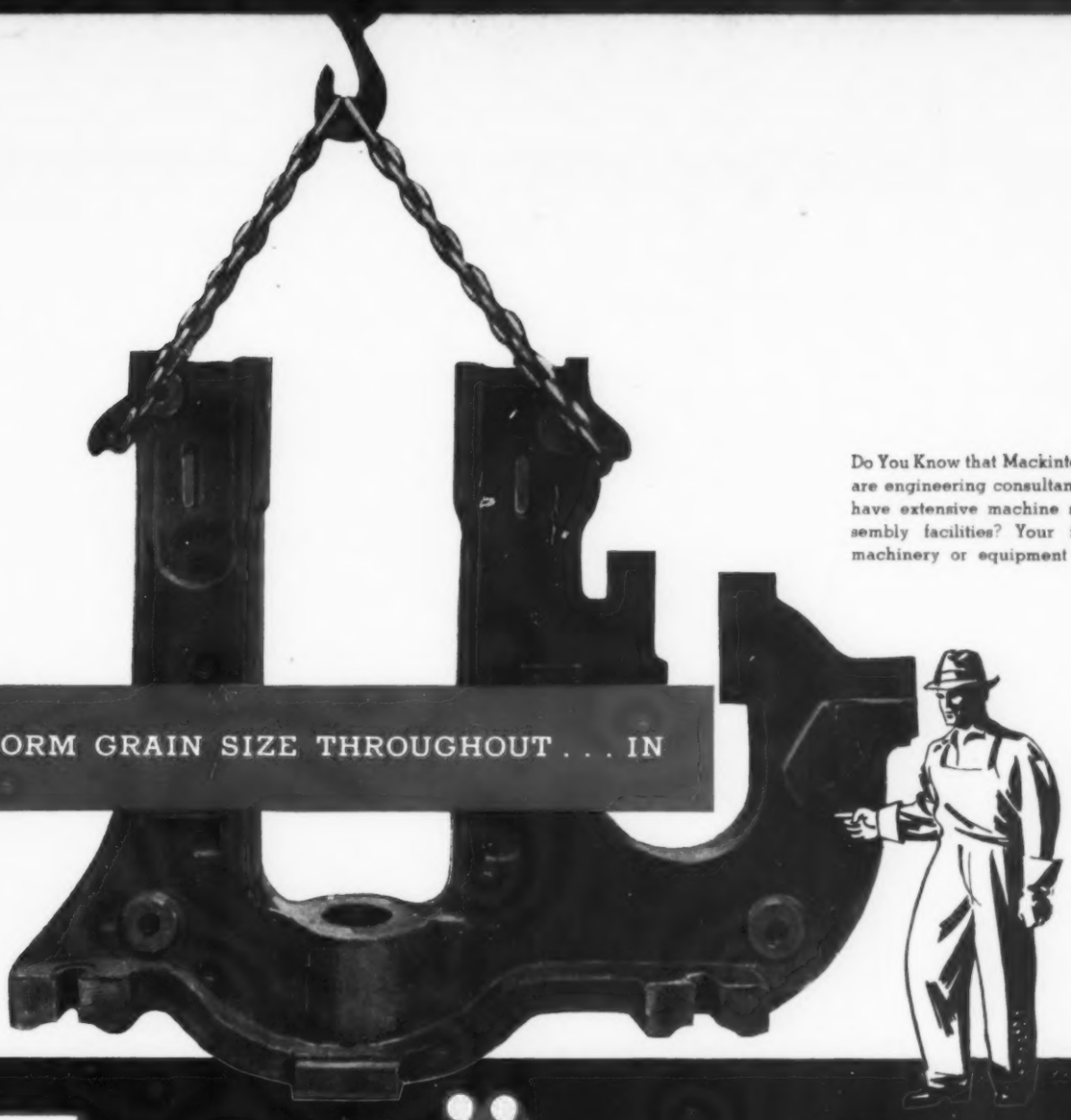
LABORATORY AND FIELD TESTS prove that Ruptors increase circuit interrupting efficiency. Shown here is a Type DZ-40, 3 pole, 600 amp, 15 kv oil circuit breaker with Ruptor.

Get the whole story. Find out how "QUICK-QUENCH" action can serve you. Let your Allis-Chalmers representative, in the district office near you, show you how to get higher interrupting capacities . . . how to get lower maintenance costs!

932

SWITCHGEAR DIVISION
ALLIS-CHALMERS
MILWAUKEE·WISCONSIN

METALCLAD SWITCHGEAR • SWITCHBOARDS • OIL CIRCUIT BREAKERS • REGULATORS • MOTOR STARTERS • CUBICLES • SWITCH HOUSES



Do You Know that Mackintosh-Hemphill are engineering consultants? That they have extensive machine shop and assembly facilities? Your inquiries for machinery or equipment are invited.

UNIFORM GRAIN SIZE THROUGHOUT . . . IN

"Techni-castings

The same "Techni" Process introduced and used by Mackintosh in the casting of "Technichill" Rolls and other "Techni" Rolls . . . is also used in the production of "Techniron" and "Technisteel" Castings.

These Castings show the same improvement in quality as found in the rolls made under this exclusive new process and, in addition, have a very great increase in strength over castings of equivalent composition made under standard practice.

They show a remarkable uniformity of grain size and hardness in both large and small sections of the same casting. Massive section "Technisteel" castings, weighing up to 100,000 lbs. and "Techniron" castings up to 250,000 lbs. have uniform grain size throughout the whole cross section.

MACKINTOSH-HEMPHILL COMPANY, Pittsburgh and Midland, Pa.

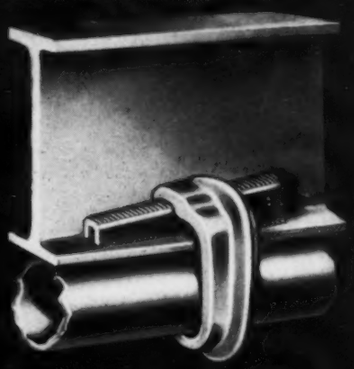
THE "TECHNI" PROCESS

. . . is a fundamentally new method of melting furnace control, and has resulted in remarkable improvements in quality, toughness, strength of chill and other characteristics. It is available also in

"Technichill" Rolls
"Technigrain" Rolls
"Technisand" Rolls
"Technalloy" Rolls

THE ROLLS WITH THE RED WABBLERS

CROUSE-HINDS
Wedgtite
PIPE HANGERS

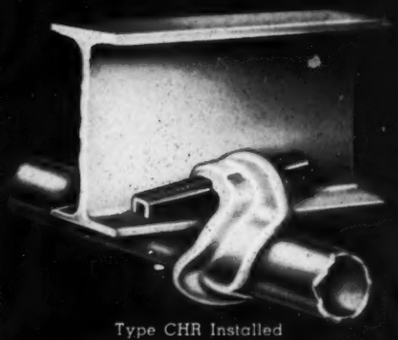


Type CHP Installed
Pipe Parallel with a Structural Shape

Wedgtite pipe hangers are quickly and easily installed, as only a few blows of a hammer are necessary. These hangers can be used on "I" beams, channels, or other structural shapes.

The wedge is provided with saw teeth which bite into the flange and prevent loosening due to vibration. The wedge is interchangeable with all types and sizes of hooks.

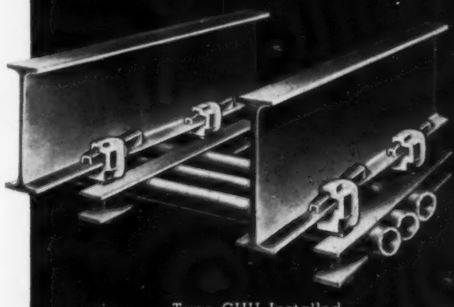
In types CHP and CHR, one end hooks under the pipe and the other end hooks over the flange of the supporting steel beam. The end that hooks over the flange has a groove into which the wedge is driven, tightly drawing the pipe against the flange, and securely holding it in position.



Type CHR Installed
Pipe Running at Right Angles to
a Structural Shape

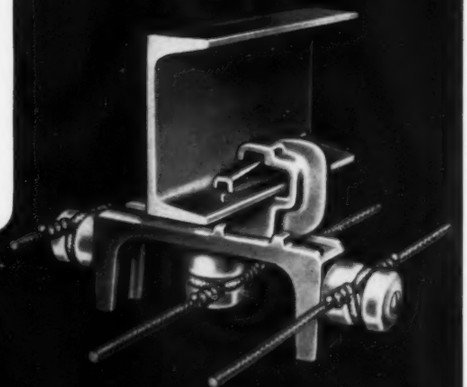
Type CHU is wedged to the flange independently of the pipe or group of pipes which is to be supported. A bolt is used for suspending the pipe or group of pipes. The head of the bolt rests securely in a pocket in the hook of the hanger. This pocket takes the head of a ½-inch bolt. The bolt can be inserted after the hanger has been secured to the flange.

Type CHA consists of a type CHU hanger and a bracket to carry two or three porcelain knobs for the wires. The bracket is attached to the CHU hanger with a bolt and nut. The bolt can be loosened and the bracket turned to accommodate wire running either parallel with or at right angles to the structural shape. Three holes are drilled and tapped in the bracket for each location of porcelain knob so that a machine screw suitable for the size of knob to be used may be selected.



Type CHU Installed
Pipes Suspended from a Structural Shape

Wedgtite pipe hangers are also useful in connection with water pipes, steam pipes, and sprinkler systems.



Type CHA Installed
For Carrying Open Wires on Structural
Steel Work

A Nationwide Distribution Through Electrical Wholesalers

Condulet Catalog No. 2500 will be sent on request.

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Atlanta — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit
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CH654

Specify HYDRAULIC-ACTUATED

WAGNER INDUSTRIAL BRAKES

WHERE DEPENDABLE SERVICE IS *Essential*

Wagner

HYDRAULIC-ACTUATED BRAKES

Ruggedness characterizes every construction detail of Wagner Hydraulic-Actuated Industrial Brakes . . Welded steel parts . . . Hardened pins and bushings . . . and Cannonite brake wheels, are just a few of their many advantages. They are built to "stand-up" under the kind of service that usually "takes the life" out of ordinary brakes.

Type MTW is for ordinary bridge service, the type MTWM is equipped with spring-set shunt solenoid release to provide locking device where desired.

If you want low brake maintenance of Cranes, Coke Pushers, Transfer Cars and similar equipment . . . Specify Wagner Brakes. The coupon at the right will bring complete information immediately.

for
CRANES
COKE PUSHERS
TRANSFER CARS
and Similar applications

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WAGNER ELECTRIC CORPORATION
INDUSTRIAL BRAKE EQUIPMENT
4900 Baum Blvd. **Pittsburgh, Pa.**

GENTLEMEN: We are interested in Wagner Hydraulic-Actuated Industrial Brakes for application as checked below:

☐ CRANES ☐ COKE PUSHERS ☐ TRANSFER CARS

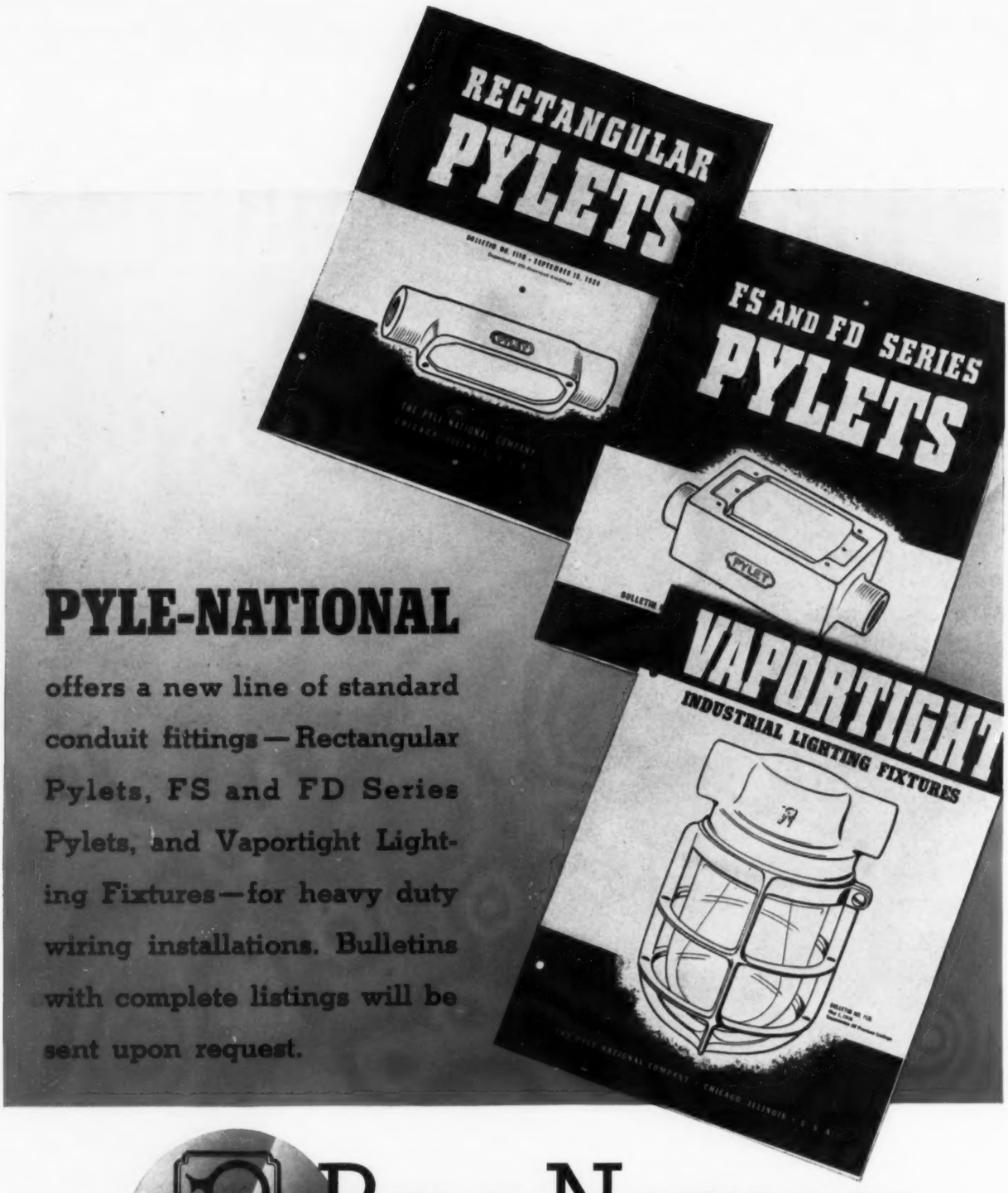
☐ Other Application .....

Name .....

Company .....

Address .....

City ..... State .....



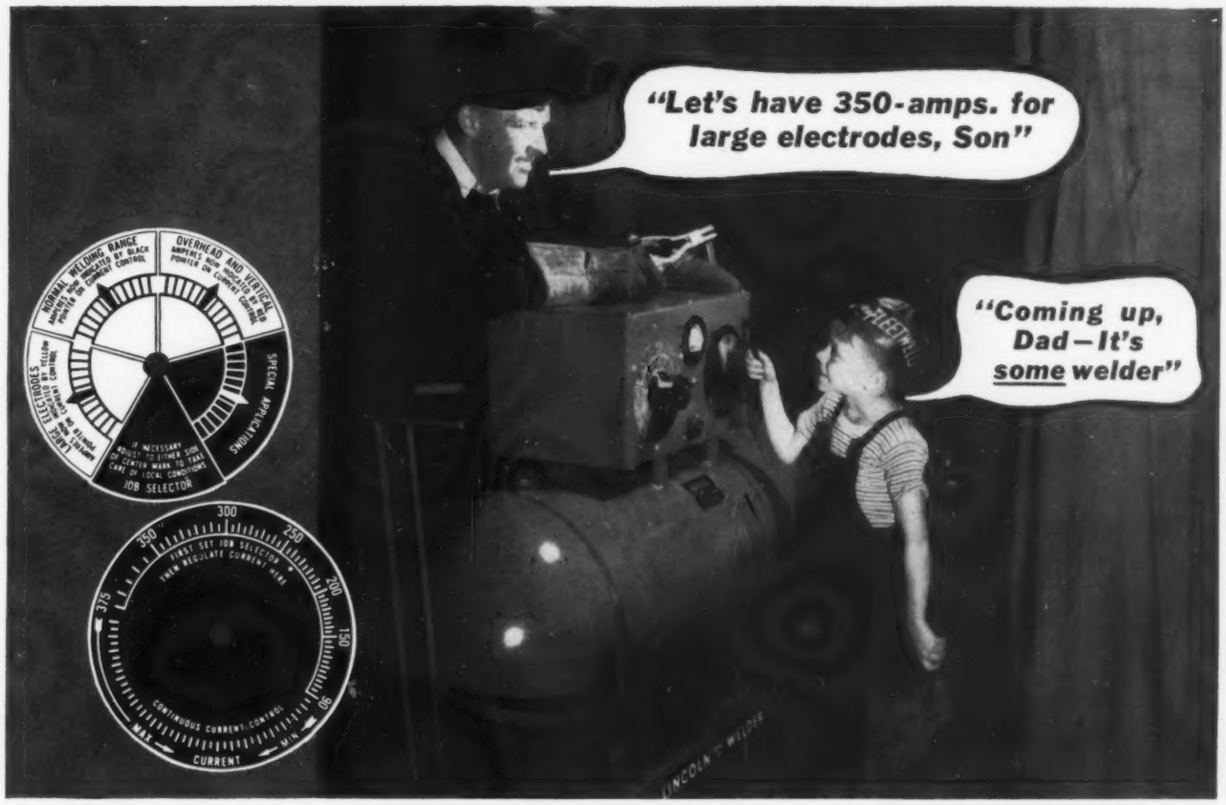
PYLE-NATIONAL

offers a new line of standard conduit fittings — Rectangular Pylets, FS and FD Series Pylets, and Vaportight Lighting Fixtures — for heavy duty wiring installations. Bulletins with complete listings will be sent upon request.

PYLE-NATIONAL

The Pyle-National Company, *General Offices and Works,* 1334-58 North Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco

CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS



Self-Indicating control of the new "Shield-Arc" assures highest quality welds at lowest cost . . . on every job

● Easy? Take it from this 7-year-old "helper." He says, "Of course I can't weld . . . that takes training and experience . . . but I can set this new Lincoln. Everything is right on the dials."

Self-Indicating Job Selector and *Self-Indicating* Current Control . . . both continuous in operation . . . make it possible to set the new *"Shield-Arc"* for the right TYPE and SIZE of welding arc easily, quickly and positively. This assures maximum quality and maximum speed for every welding job, every time.

This new Lincoln Welder gives you these additional benefits:

WIDE RANGE. For all types of work and exceptionally wide range of welding current. *Dual Continuous Control* provides literally thousands of combinations of voltage and current.

FASTER WELDING. Larger electrodes can be used because the welder is *Self-Protected against burnout.*

MINIMIZED SPATTER. *Independent Excitation* contributes to this money saving feature.

STEADY ARC. Under all welding conditions. *Laminated Magnetic Circuit* contributes to the welder's remarkable arc stability.

. . . and 25 other cost-cutting features. Consult the nearest Lincoln office or mail the coupon.

THE LINCOLN ELECTRIC CO., Dept. Z-553, Cleveland, O.

☐ Have a Lincoln man call to explain the new Self-Indicating *"Shield-Arc."* ☐ Send free bulletin 412-A.

Name _____ Position _____

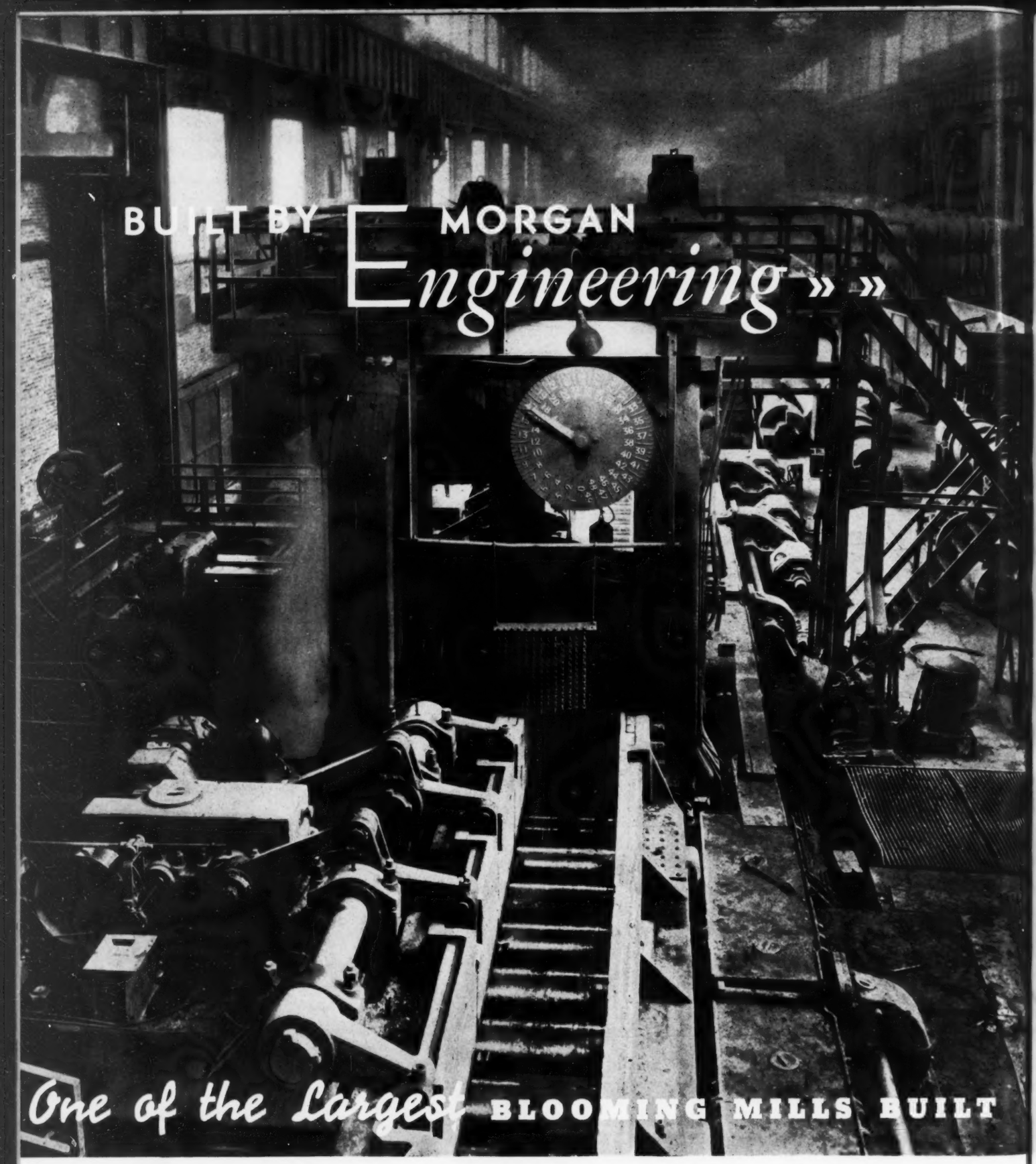
Company _____

Address _____

City _____ State _____

LINCOLN

LARGEST MANUFACTURERS OF ARC WELDING EQUIPMENT IN THE WORLD



● Few blooming mills have been built during the past ten years, but this is one of the largest ever built and one of the newest. This 54″ blooming mill has one-piece steel castings for its housings, insuring rigidity. A two-cylinder roll balance allows for minimum headroom. Manipulator is of the over-head type, compact and accessible. Finger lifts and side-guards, each operated by two motors in series, assure quick acceleration and more tonnage. Morgan responsibility extends from design to construction and installation–assuring mill operators of satisfactory production as specified, and traditional integrity of Morgan engineering.

★

★ **DESIGNERS • MANUFACTURERS • CONTRACTORS**

★ BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS
ELECTRIC TRAVELING CRANES • CHARGING MACHINES

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ELECTRIC WELDED FABRICATION • LADLE CRANES

★ STEAM HAMMERS • STEAM HYDRAULIC FORGING
PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

★ **THE MORGAN ENGINEERING CO., Alliance, Ohio**
Pittsburgh, 1420 Oliver Bldg. New York, 11 W. 42nd Street

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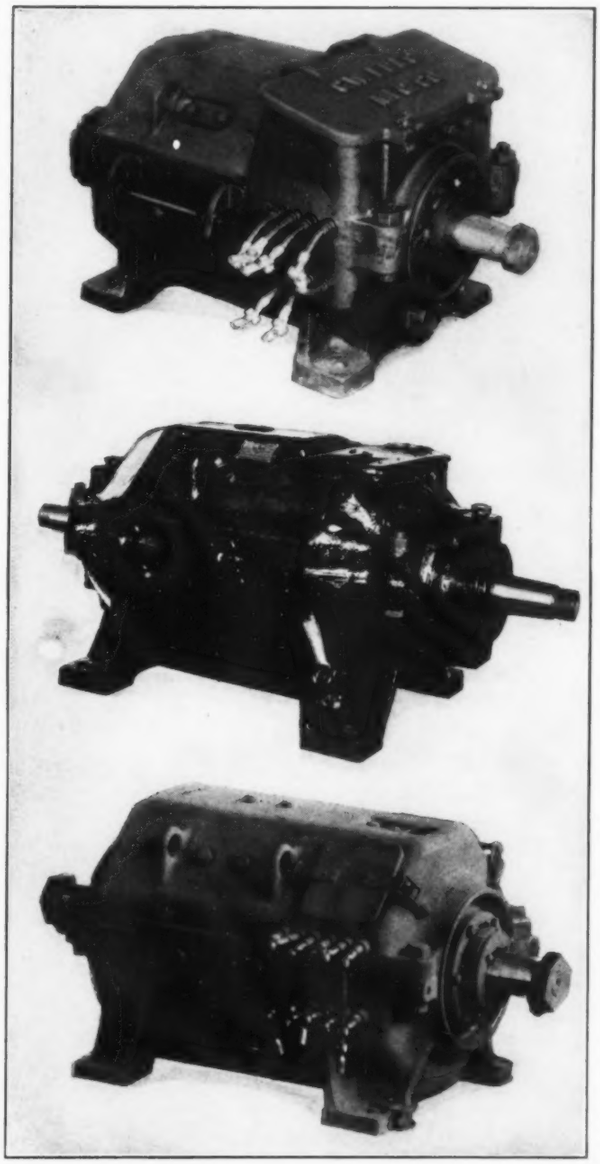
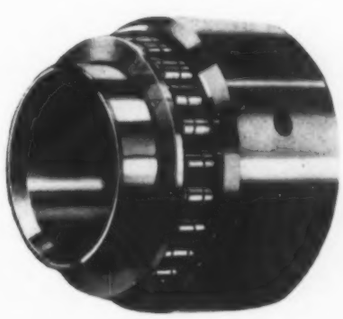
HYATT protection for your Mill Motors



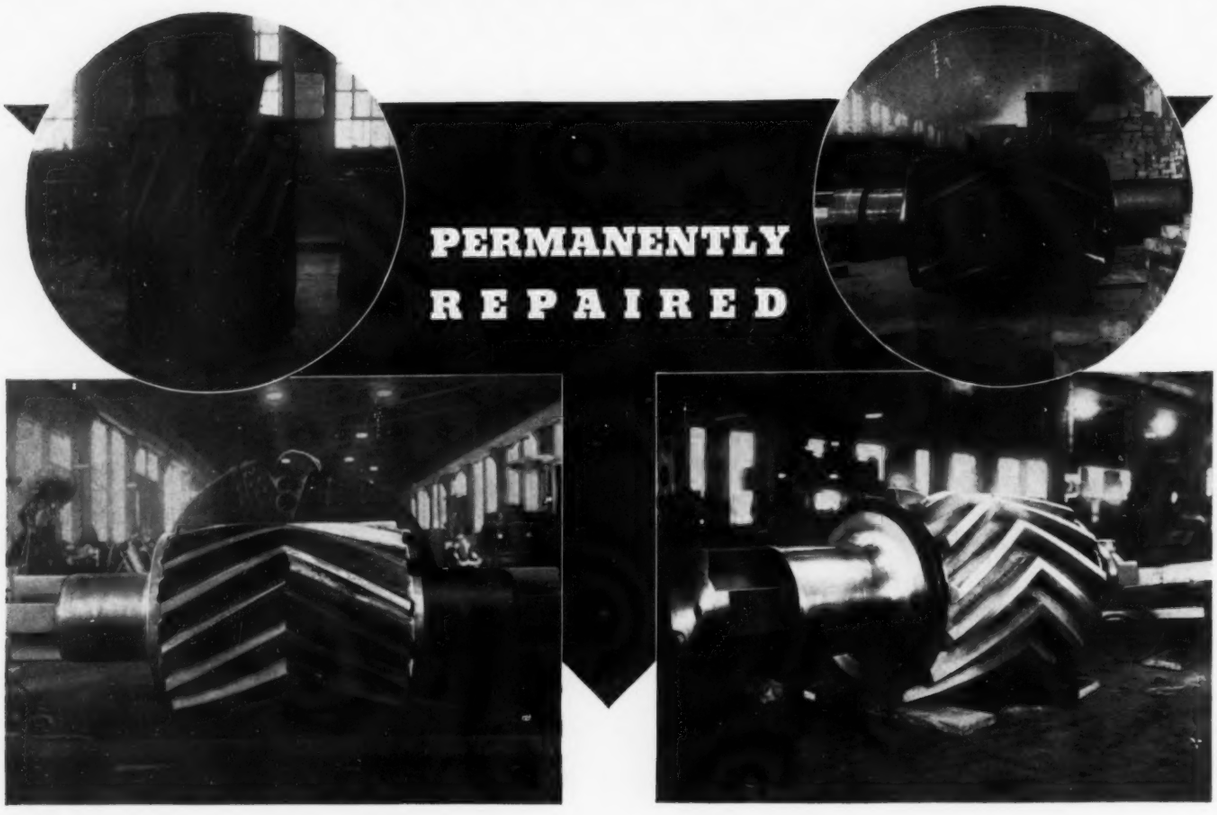
For Mill Motors by
GENERAL ELECTRIC • WESTINGHOUSE
CROCKER-WHEELER
Hyatts are available, as standard equipment, or for change-overs

To assure dry windings and proper armature clearance at all times equip your mill motors with Hyatt Roller Bearings.

Hyatt construction permits the simplest kind of mounting giving you a long-lived installation requiring no maintenance beyond the occasional addition of grease lubricant. Hyatt Bearings Division, General Motors Corporation, Harrison, Detroit, San Francisco. Hyatt Roller Bearing Sales Company, Chicago and Pittsburgh.



HYATT
Roller Bearings



at a small fraction of replacement cost

It is never difficult to put your finger on the economy of Thermit Welding. The savings effected by this easy method of making permanent repairs invariably run to substantial amounts.

Welding a new end to one of these 40-inch mill bloomer pinions and forming a new tooth in the other by means of Thermit were accomplished at a small fraction of the cost of new pinions.

The reclamation department prepared to Thermit Weld pays large dividends. Broken housings, charging peels, wobbler ends and an infinite number of other parts can be repaired permanently and inexpensively with Thermit. What's more, in emergencies, speedy Thermit repairs often save thousands of extra dollars by enabling essential equipment to be returned quickly to service and avoiding long, costly shut-downs.

Consider the possibilities for such economies in your mill. As a first step write for the booklet: "Thermit Welding—Industry's Master Maintenance Tool." It will answer many questions.

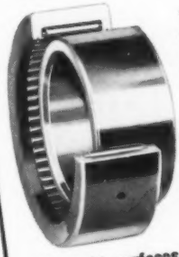
THERMIT WELDING

METAL & THERMIT CORPORATION, 120 BROADWAY, NEW YORK, N. Y.
ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

DOING OUR BEST

TO KEEP UP WITH THE DEMAND!

STANDARD SERIES
QUILL BEARING



★ ONE-PIECE channel-shaped outer race with rollers definitely retained.

★ Simplified design—No fragile parts—Easy to assemble.

★ Rigid surfaces, accurately hardened and ground, confining rollers endwise.

★ High load carrying capacity—minimum space requirement.

★ Low cost made possible through large production. Simplified design.

★ Correctly proportioned rollers with husky curvilinear trunnions.

Carried in stock in sizes for shafts from ½" to 5"

WHEN the Standard Series of Bantam Quill Needle Bearings was introduced in September we said "Carried in Stock." And we meant it! But we had no idea that the demand for these bearings, in a number of sizes, would far exceed our ability to produce them. So, for a short time we were unable to make immediate shipments.

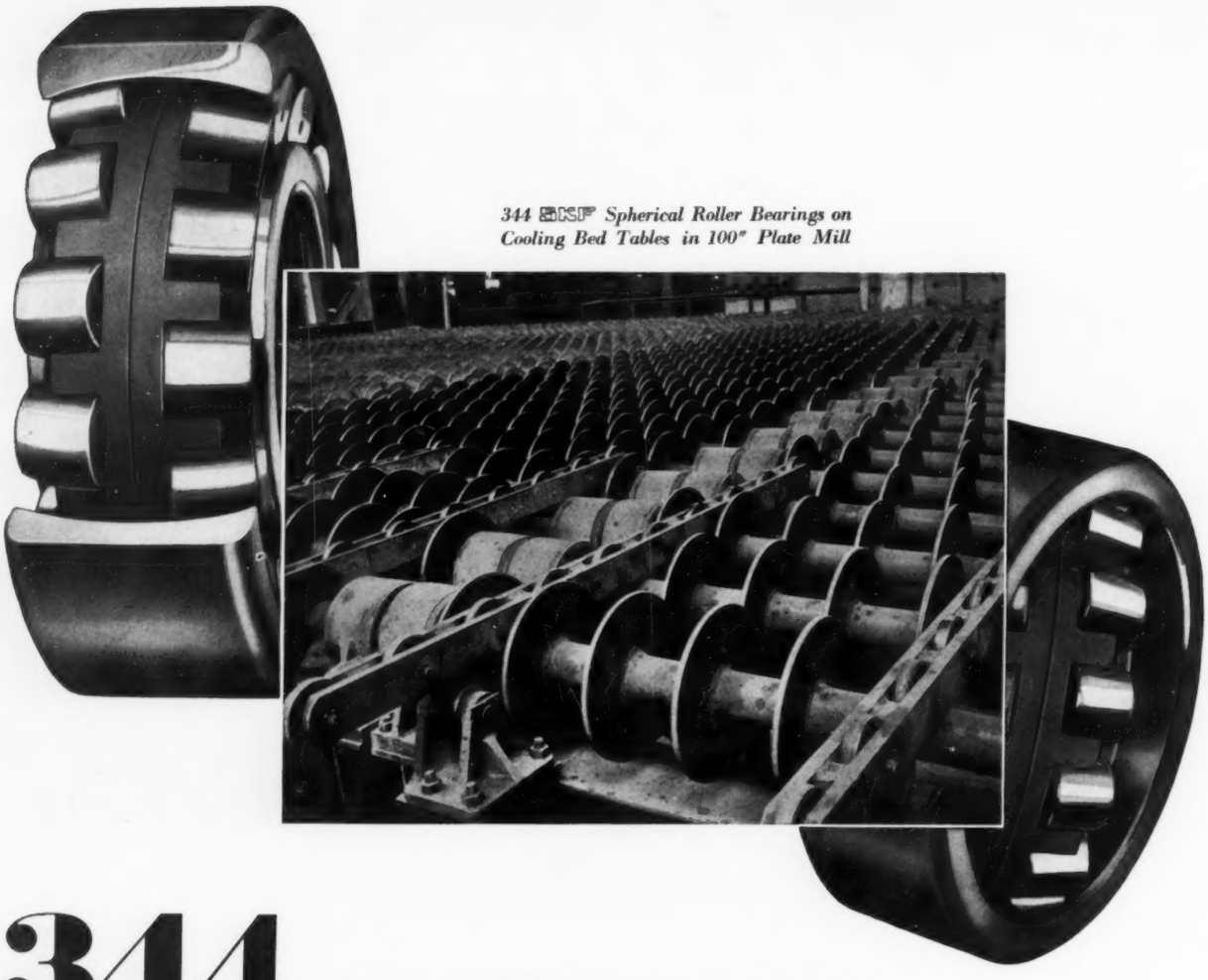
We thought that a bearing with all the advantages of *lower cost, higher capacity and longer life* offered by the Bantam Standard Quill Bearing would get an immediate response. But we hadn't expected such a quick acceptance.

Production has now been stepped up. By the time this message reaches you, we can again say "Carried in Stock" and mean it. Your orders will be promptly filled in all sizes from ½" to 5" shaft.

BANTAM BEARINGS CORPORATION
SOUTH BEND, INDIANA
Subsidiary of THE TORRINGTON CO.
Torrington, Conn.

BANTAM
BEARINGS

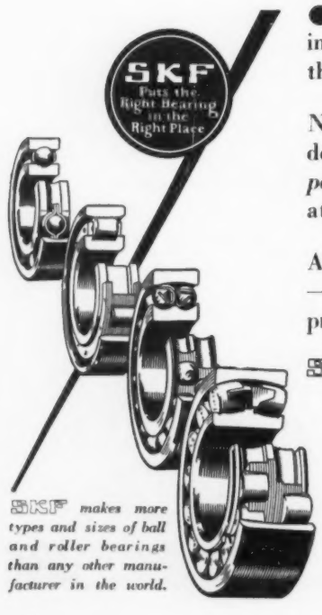
TAPERED ROLLER • • • STRAIGHT ROLLER • • • BALL BEARINGS



344 SKF Spherical Roller Bearings on Cooling Bed Tables in 100" Plate Mill

344 SKF SPHERICAL BEARINGS

STEP UP PRODUCTION ON COOLING BED TABLES



SKF makes more types and sizes of ball and roller bearings than any other manufacturer in the world.

● 344 SKF Spherical Roller Bearings work together on these Cooling Bed Tables in a 100" Plate Mill. That's proved by the fact that the entire unit can be turned by hand by twisting at the coupling.

Not only does SKF inherent rolling alignment compensate for shaft deflection, but assures HIGH CAPACITY at all times, *for there is no possibility of cramping or binding.* Permanently adjusted, the only attention they require is infrequent lubrication.

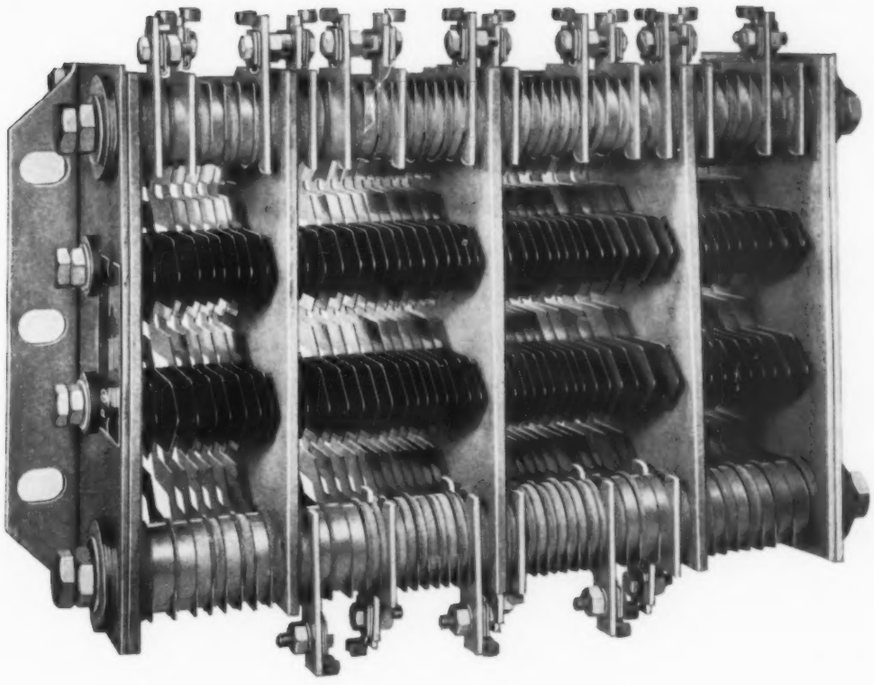
All of which means plate moves smoothly, certainly and continuously —at the lowest cost per bearing hour. It will pay *you*, too, to improve the performance of your rollers with SKF Bearings.

SKF INDUSTRIES, INC., PHILADELPHIA, PENNA.

4217

SKF

BALL & ROLLER BEARINGS



TESTED IN SERVICE

Several hundred Post-Glover Chromium Steel Grid Resistors are now in service in various types of Face Plate Controllers. A great many of these were installed on the hardest service in the plant for trial. Practically every trial has resulted in repeat orders.

Try one of these resistors and discover for yourself why Steel Mill Engineers call it

"The RESISTOR you can INSTALL and FORGET"

P-G

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI, OHIO

Big Savings
made by Vane Controlled Draft Fans

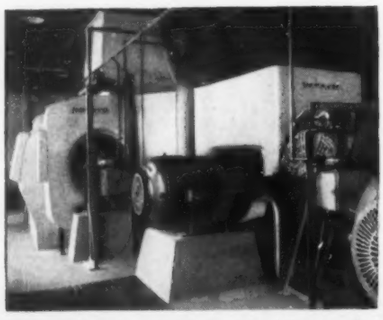
TYPICAL EXAMPLE AT RCA-VICTOR

R.C.A. Victor selected two Forced Draft and two Induced Draft Sturtevant Patented Vane Controlled Fans for their new 120,000 lb. steam per hour boilers. They were convinced of their many advantages resulting in worthwhile savings.

Sturtevant Vane Control Advantages

1. Assures quick, accurate regulation of pressure and volume.
2. High efficiency.
3. Reduces motor power consumption.
4. Permits use of constant speed motors, instead of more costly variable speed motors.
5. Eliminates the expensive and complicated control required for variable speed motors.

Because of the *proved* advantages of Sturtevant Vane Control Draft Fans, they have been selected for many recent plants including:



Sturtevant Vane Controlled Induced Draft Fans installed at RCA-Victor Manufacturing Company, Camden, N. J.

One of two Sturtevant Vane Controlled Forced Draft Fans installed in plant of RCA-Victor Manufacturing Company, Camden, N. J.

Standard Oil Co. of Southern California
Consolidated Edison Co. of N.Y.
Virginia Electric and Power Co.
Tampa Electric Co.
Spreckels Sugar Co.
Richfield Oil Co.
Pacific Gas and Electric Co.
Louisiana Steam Products Co.

Our nearest office will gladly supply complete information.

B. F. STURTEVANT COMPANY
HYDE PARK, BOSTON, MASS., *Branches in 40 Cities*
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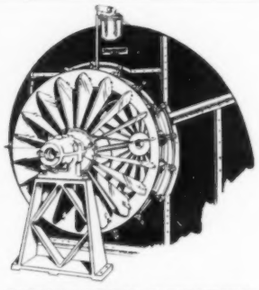
Galt, Toronto, Montreal

Sturtevant
REG. U. S. PAT. OFF.
Puts Air to Work

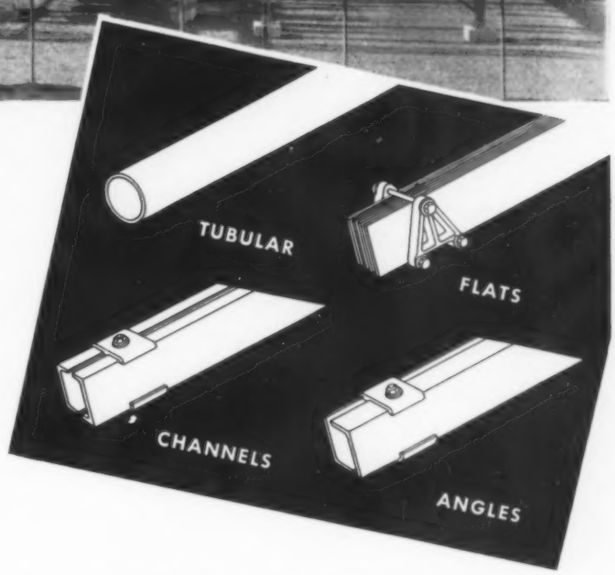


QUICK ACTION - FLEXIBILITY EFFICIENCY

1. Pressure and volume regulated by movable vanes, located in the Fan inlets, as illustrated above. Vanes operated either manually or by automatic combustion control.
2. Result: quick, accurate response to varying load requirements.
3. Combines the flexibility and immediate response of dampers with efficiency of variable speed control.

DRAFT FANS · TURBINES · GEARS · ECONOMIZERS · AIR HEATERS

Tubular Alcoa Aluminum Bus installed at an outdoor substation of the Appalachian Electric Power Company.



STIFFNESS of the Alcoa Aluminum tubular bus, in combination with the arched shapes into which it is formed, makes the overhead construction at this outdoor substation extremely substantial. Note that, although few supports are employed, the buses line up with military precision.

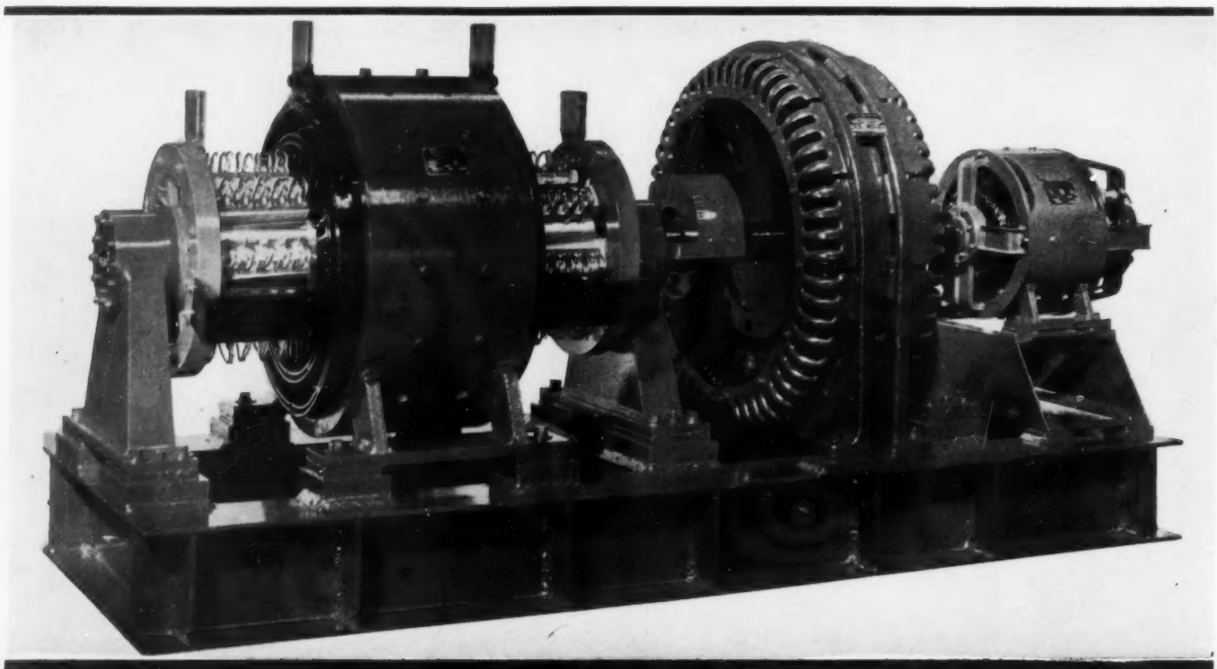
For equal current capacity, Aluminum weighs less than half as much as other materials, an advantage obtained with all types of Alcoa Aluminum bus bar; flats, tubular, channels and angles. Supports can be lighter and more widely spaced, greatly reducing the cost of the construction. Installation labor is less. Bus bars can frequently be placed out of the way, in locations where heavier materials would not be practical.

Highly resistant to corrosion, Aluminum bus bars withstand the weather. They give long life in plating rooms and other manufacturing departments where processes produce corrosive fumes.

Standard methods and fittings are used with Alcoa Aluminum buses. Our engineers will gladly work with you in designing and estimating on bus construction. ALUMINUM COMPANY OF AMERICA, 2128 Gulf Building, Pittsburgh, Pennsylvania.

ALCOA

ALCOA · ALUMINUM



For Continuous Electro-Plating and Electro-Cleaning

USE THESE "STEEL MILL TESTED" LOW VOLTAGE GENERATORS

COLUMBIA engineers fully realize that the continuous electro-plating, pickling or cleaning of steel strip or sheet depends upon a reliable source of high ampere, low voltage current. Consequently, they have developed over a period of years a line of performance proven generators to meet the rigid requirements of this type of service.

Columbia Generators have frames of all steel welded construction making for a more compact unit; have slightly higher armature speeds for greater efficiency and lower first cost; sparkless commutation from no load to 150% load resulting in long brush life; are equipped with Timken Double Row tapered roller bearings.

Columbia Generators and Motor Generator Sets are built in sizes of ½ to 250 KW, 100 to 40,000 amperes, 6 to 60 volts. Bulletin 700 describes these efficient units. May we send you your copy?

Illustration above shows a 5,000 ampere, 6 volt, 450 R. P. M. 3 bearing synchronous motor-generator set with direct connected exciter.

COLUMBIA ELECTRIC MFG. COMPANY
4505 HAMILTON AVENUE CLEVELAND, OHIO

COLUMBIA

LOW VOLTAGE GENERATORS AND MOTOR GENERATOR SETS

NEW YORK CITY: Okonite cables installed to carry signals calling out this kind of fire apparatus 22 years ago, were recently removed from 125th Street, carefully tested and found fully qualified to give many more years of service.

NEW JERSEY: The recent hurricane, uprooting giant trees and levelling pole-lines, failed to interrupt the continuous operating record of these 4150-volt Okolite insulated aerial cables which had already survived a devastating tornado in July.

Installations Illustrated

A pictorial record of the successful use of Okonite wires and cables under extraordinary and unforeseen conditions.

MICHIGAN: Okonite multi-conductor signal cable, though buried in soil impregnated with waste from chemical plants, is fully protected by a non-metallic sheath of corrosion-resistant Okosheath.

OKOPRENE insulated and jacketed cable (compounded with Neoprene) is used exclusively by a large rayon manufacturer for the lead-ins to spinning motors which are exposed in service to oil, acid, and solvent vapor conditions. Heat resistance is also required of the insulation because of the necessity of baking the lead-in wire at the same time the motor windings are baked.

You, too, may have a wire or cable problem that is tough. If so, let our engineers consult with you.

1938 Marks Our 60th Year of Service

OKONITE **THE OKONITE COMPANY**

Founded 1878

EXECUTIVE OFFICE: PASSAIC, NEW JERSEY

HAZARD INSULATED WIRE WORKS DIVISION — THE OKONITE-CALLENDER CABLE CO., INC.

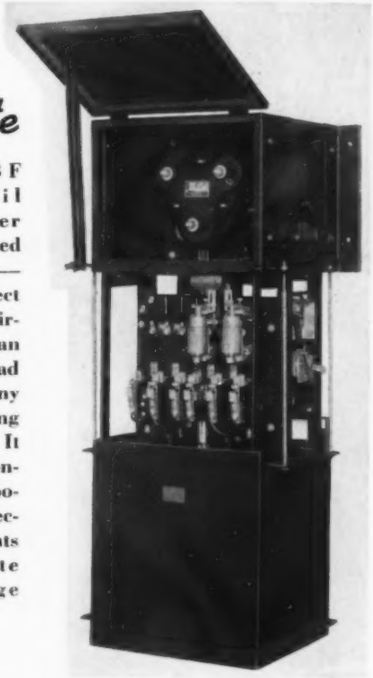
New York · Boston · Seattle · Buffalo · Chicago · Dallas · Detroit · Atlanta
Philadelphia · Los Angeles · Pittsburgh · St. Louis · Washington · San Francisco

OKONITE QUALITY CANNOT BE WRITTEN INTO A SPECIFICATION

Two views of the Double Carry-over Cooling Bed. This bed receives the bars from the Finishing Train and Dividing Shears, and passes them on to the Bar Shears. Notice that the bars lie straight and are even at the ends. In the background is seen the Chain Coil Conveyor, automatic "Take-off," and Coil Hook Carrier. MORGAN CONSTRUCTION COMPANY, Worcester, Massachusetts.

R47

It's Complete



Type 900 K B F Combination Oil Immersed Starter includes: reduced voltage starting — Safety Disconnect Switch—Rowan Air-Seal Fuses—Rowan Magnetic Overload Relays—and many other outstanding Rowan features. It is, in fact, a control unit incorporating all the necessary requirements of a complete reduced voltage starter.

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

AN OIL IMMERSED PUSH BUTTON FOR EVERY CONTROL REQUIREMENT

The Rowan Controller Co. manufactures the most complete line of oil immersed push buttons. Types are available not only for standard applications but for the special requirements of unusual installations. Write for bulletin 35112 giving complete information.

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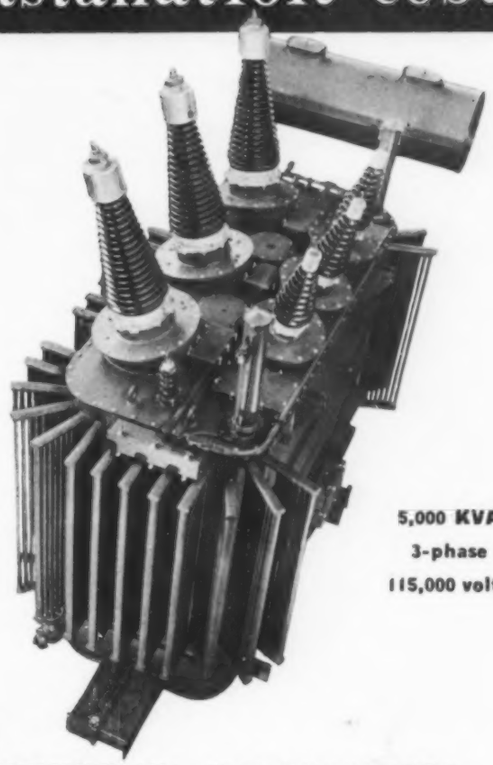

5,000 KVA
3-phase
115,000 volts

PENNSYLVANIA TRANSFORMERS *are delivered with radiators permanently welded to the tank and completely filled with oil,* which eliminates the inconvenience and cost incident to attaching radiators and filling with oil after delivery. The *air is removed* by vacuum process from the core, coils and oil, *before shipment....* an added advantage possible with this type of construction.

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PENNSYLVANIA TRANSFORMERS

Pennsylvania

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1701 Island Ave., N. S., Pittsburgh, Pa.

Last stand of hot mill; screw-downs operated by De Laval worm gear sets.

Roughing stand; screw-downs and edging rolls are operated by De Laval worm gear sets.

Six stands of hot finishing mill; screw-downs operated by De Laval worm gear sets.

MECHANICAL ACHIEVEMENT *demands* PERFECT DETAILS

The new 96-in. continuous strip mill, with rolling machinery built by the Mesta Machine Company, for the Pittsburgh Works of the Jones & Laughlin Steel Company, has a monthly capacity of 60,000 gross tons of steel. In this mill are incorporated the latest improvements for making the highest quality products. Tremendous pressures are required to roll some of the modern alloy steels, and the duty performed by the

DE LAVAL WORM GEAR SETS

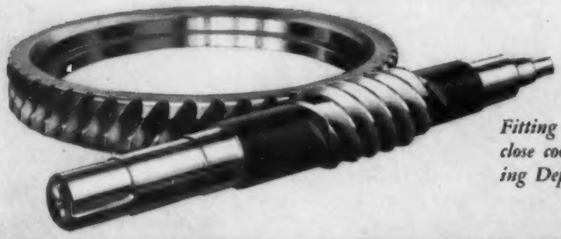
which actuate the screw-downs, and also the edging rolls of the roughing stand, is more severe than is encountered in most industries. These speed reducers are themselves products of a policy of high quality manufacture.

Their design is based upon reliable data obtained from laboratory tests and from years of field experience with a great variety of applications.

The materials used are bought under the control of thorough specifications and laboratory tests.

Machining is done on special tools to limit gages on an interchangeable basis and by special methods developed by De Laval experience extending back to 1901 in building high grade speed transformers.

Back of De Laval worm gears is a well established and reliable concern, having an unsurpassed record of making good in whatever it offers and promises to do.



Fitting of a De Laval worm gear drive to the user's problem is done by close cooperation with his designing engineers. The De Laval Engineering Department will gladly assist with data and advice in solving your speed transformation problems.

1106

DE LAVAL *Steam Turbine Co.*
TRENTON, N. J.

MANUFACTURERS OF STEAM TURBINES; PUMPS — CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT; CENTRIFUGAL BLOWERS AND COMPRESSORS; WORM GEARS, HELICAL GEARS; HYDRAULIC TURBINES AND FLEXIBLE COUPLINGS • • • SOLE LICENSEE OF THE BAUER-WACH EXHAUST TURBINE SYSTEM

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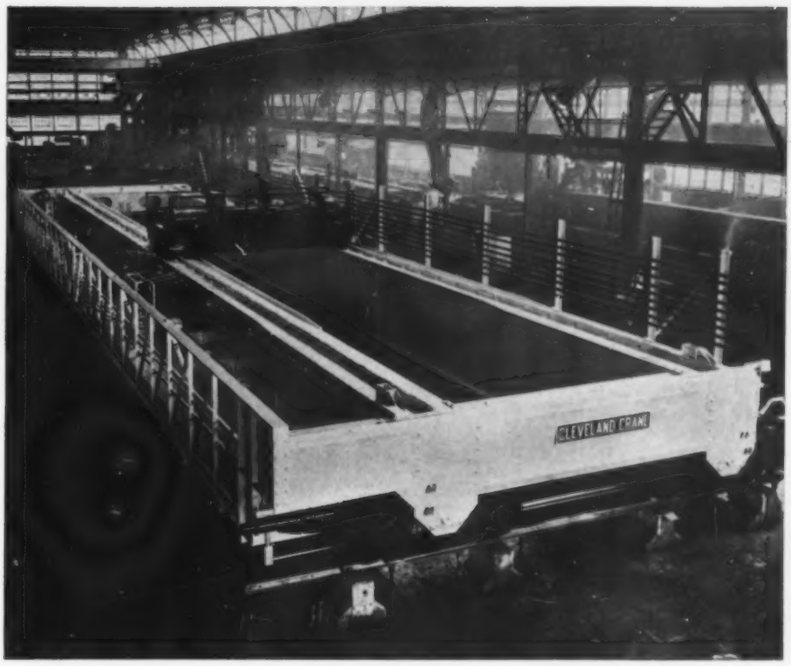
ALL WELDED STEEL MILL CRANES



• One Hundred and Twenty Foot Span (120'-0") sixteen foot spread (16'-0") fifteen ton three motor All Welded Cleveland Steel Mill Crane.

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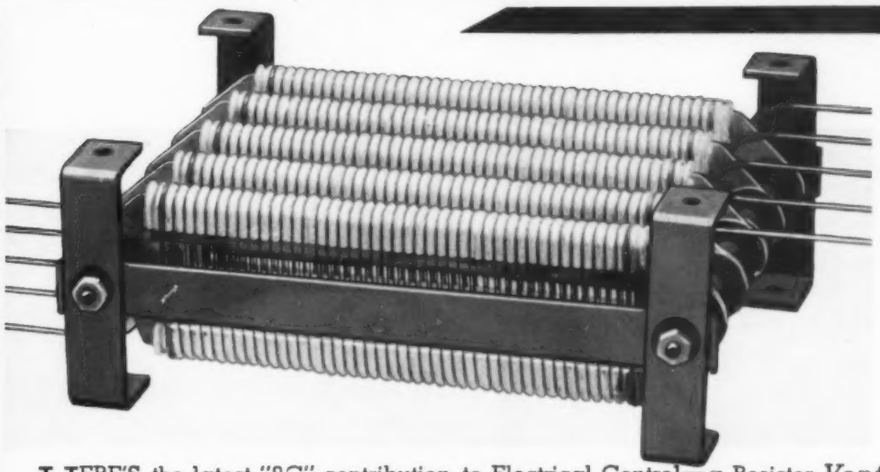

VENT WOUND FOR VENTILATION!
BULLETIN 113 RESISTORS

HERE'S the latest "3C" contribution to Electrical Control—a Resistor *Vent Wound* to provide unrestricted air circulation around the Resistor Wires over the *entire length* of the Resistor Unit. Sectional Porcelain Insulators mounted on full length steel cores are grooved to hold Resistor Wires in position and prevent sagging or contact of adjacent wires when heated.

For smaller A. C. and D. C. motor drives, and as field and discharge circuits where units of this capacity can be used, these "3C" Bulletin 113 Vent Wound Resistors are rugged and dependable.

Our nearest office is at your command for further information.

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OHIO SEPARATION MAGNETS—With Stronger Pulling Capacity.

OHIO MAGNET CONTROLLERS—With Automatic Quick Drop to speed up operation and With Ohio Arc Suppressor to reduce the arc and make the Contacts and Arc Shields last much longer.

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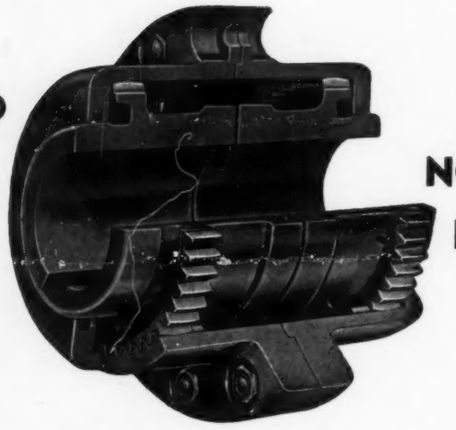

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NO WELDED PARTS
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It gives full compensation for the unavoidable errors in alignment or those caused by changes of temperature, wear of bearings, vibration, etc. It also permits free lateral float to connected shafts, and prevents torsional motions. Stronger than the connecting shafts. Capable of sudden reversals at high speed or heavy duty, slow speed drives without strain to the coupling or the machinery it connects. Simple in design, no springs, pins or bushings, self-aligning, silent and vibrationless at all times.

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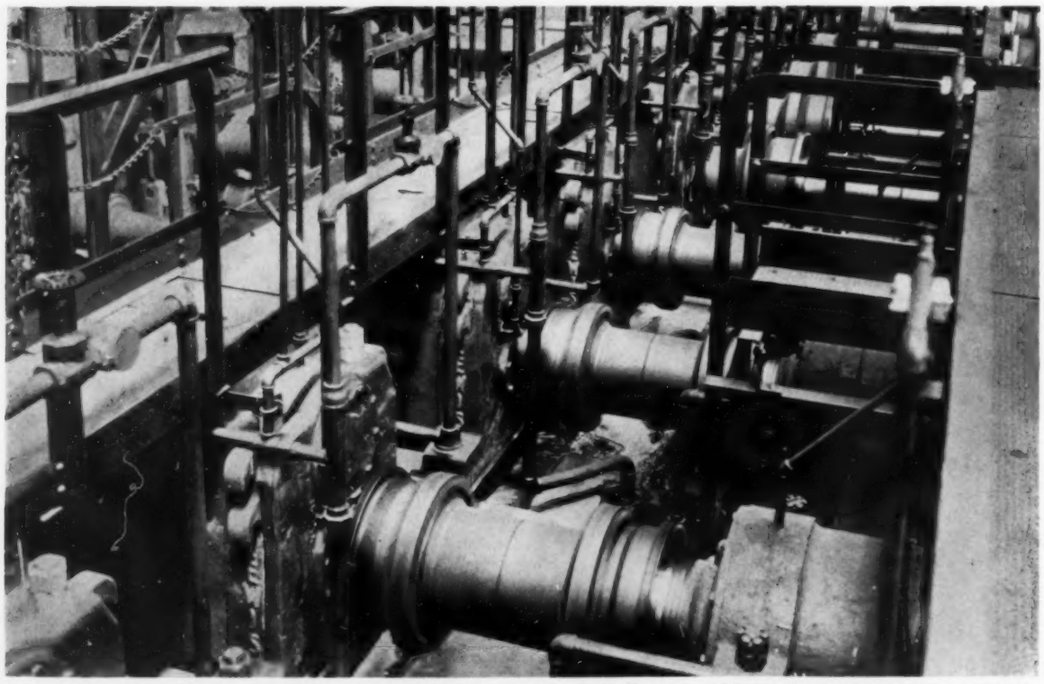

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To attain the ultimate in precision and dependability Farrel-Birmingham uses TIMKEN Tapered Roller Bearings in its heavy duty mill drives. This is in common with an overwhelming majority of steel mill equipment builders.

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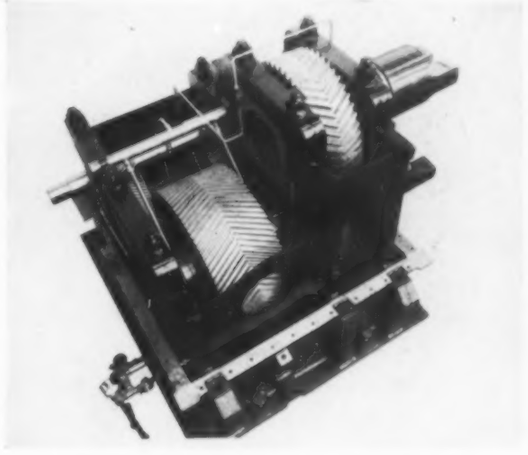
TIMKEN
TAPERED ROLLER BEARINGS

One of five special Timken Bearing Equipped Farrel-Birmingham Drives designed to drive an electric weld tube mill.



Combined gear drive and pinion stands. Made and equipped with TIMKEN Bearings by Farrel-Birmingham for driving 20½ and 53 x 48 4-Hi temper pass mill.

Heavy duty rolling mill drives for one of the largest strip mills.

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